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A. C. TRUE, Director.

# STUDIES ON THE DIGESTIBILITY AND NUTRITIVE VALUE OF BREAD

AT

# THE UNIVERSITY OF MINNESOTA

IN

1900–1902.

BY

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U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
*Washington, D. C., February 15, 1903.*

SIR: I have the honor to transmit herewith, and to recommend for publication as a bulletin of this Office, a report of investigations on the digestibility and nutritive value of bread carried on at the University of Minnesota in 1900–1902 by Harry Snyder, professor of chemistry in the State university and chemist of the agricultural experiment station. The studies were conducted under the immediate supervision of Prof. W. O. Atwater, chief of nutrition investigations, and Prof. Charles D. Woods, and form a part of the investigations on food of man conducted under the auspices of this Office. Thanks are due the Northwestern Consolidated Milling Company, of Minneapolis, Minn., for specially grinding samples of hard wheat, and to the Goshen Milling Company, of Goshen, Ind., and the Christian Breisch Milling Company, of North Lansing, Mich., for similar favors with respect to soft wheat.

The results of these investigations are in accord with those obtained in former studies, and indicate that fine patent flours from both hard and soft wheat are more digestible than corresponding coarse flours, though they contain somewhat less protein and mineral matter pound for pound. The investigations also show that all flours are quite thoroughly digested, and furnish experimental proof of the generally recognized fact that wheat flours of all grades are among the most important articles of diet.

Respectfully,

A. C. TRUE,
*Director.*

Hon. JAMES WILSON,
*Secretary of Agriculture.*

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# STUDIES ON THE DIGESTIBILITY AND NUTRITIVE VALUE OF BREAD.

## INTRODUCTION.

The investigations reported in this bulletin, which were carried on at the University of Minnesota in 1900–1902, are a continuation of the experiments on the digestibility and comparative nutritive value of bread made from different grades of flour reported in previous bulletins of this Office,[a] and include two series of digestion and nitrogen metabolism experiments with healthy men on a diet of milk and bread made from different grades of wheat flour, namely, straight patent, entire wheat, and graham. In the first series, which included 9 experiments carried on in 1900–1901 (pp. 20–31), the different grades of flour used were all ground from the same lot of hard Scotch Fife spring wheat. In the second series, which included 15 experiments, carried on in 1901–2 (pp. 32–50), the flours were ground from soft winter wheat.

The standard grades of flour produced by the modern process of milling are discussed in detail in a former bulletin[b] and also in later pages of this bulletin. Briefly stated, by graham flour is meant the product obtained by grinding the entire wheat kernel. Entire-wheat flour is the product obtained by removing about one-half of the coarse bran before grinding. This flour is finer than graham, but not as fine as the patent grades of flour. In milling the patent flour all of the bran is removed. Several grades of patent flour are produced, but the one most commonly found on the market, known as "standard patent," "straight patent," or "straight grade" consists of the first and second patent and first clear grades combined. By ordinary processes of milling a little over 72 per cent of the total wheat is recovered as straight or standard patent flour and about 2.5 per cent as low grade and "red dog" flours, the remaining 25 per cent being returned in the form of bran, shorts, and other offal.

During late years the relative food value and merits of these different kinds of flour have been the subject of extensive discussion; but an examination of the literature on bread and flour shows that but few digestion experiments which are really directly comparable have been

[a] U. S. Dept. Agr., Office of Experiment Stations Buls. 67 and 101.
[b] U. S. Dept. Agr., Office of Experiment Stations Bul. 101, pp. 7, 8.

made with the different kinds of flour. Wheat ranges in protein content from about 11 to 17 per cent; therefore, in order that the results of experiments may be comparable, the three kinds of flour should be milled from the same lot of wheat. In the former report it was shown that when the three different kinds of flour were ground from the same lot of hard spring wheat the graham and entire-wheat flours contained a little more protein and gave a slightly higher fuel value than the straight patent flour; but the coarser graham and entire-wheat flours had a lower coefficient of digestibility than the finer straight patent flour. Hence the straight patent flour furnished the body more nutritive material per gram or per pound than either the graham or entire-wheat flour. Because of the importance of the subject and the extensive use of wheat as a human food it was deemed desirable to repeat the work, and in so doing to extend the periods of the digestion experiments over a longer time than in the case of the experiments previously reported, in which they were only two days each. The experiments of 1900–1901 were therefore practically a repetition of those of 1899–1900, except that the digestion period in each case was twice as long, i. e., four days.

In 1901–2 experiments were made similar to those of 1900–1901, but with soft winter wheat, which is somewhat different in character from the hard spring wheat, in order to determine whether the results would be the same with flours ground from different sorts of wheat.

In connection with both series of experiments a number of analyses were made of the varieties of wheat studied and of their milling products as well as of the milk which formed a part of the diet in the digestion experiments. The necessary analyses were also made of the feces and urine to secure data for use in computing the digestibility of the food and the balance of income and outgo of nitrogen.

## METHODS OF SAMPLING AND ANALYSIS.

The analytical methods employed in these investigations were practically those recommended by the Association of Official Agricultural Chemists,[a] a few modifications suggested by experience being introduced.

A sample of each loaf of bread used during the separate digestion experiments was analyzed. One hundred grams of bread was reserved for the dry matter determination, and proportional parts of the dry matter of the bread from various loaves were united to form a composite sample, which contained a part of each loaf of bread proportioned to the size and moisture content of the loaf.

A composite sample was made of the milk in the experiments of 1900–1901 by saving, in a bottle containing 100 milligrams of potas-

[a] U. S. Dept. Agr., Division of Chemistry Bul. 46, revised.

sium bichromate, 25 cubic centimeters of the milk used at each meal. In the experiments of 1901–2 the amount of milk reserved at each meal was 50 cubic centimeters. The temperature of the drying oven was kept at about 60° C. in all cases of the determination of moisture in the feces. The bread was also dried at this temperature. Nitrogen was determined by the ordinary Kjeldahl process. In the case of wheat and its milling products and bread, protein was obtained by multiplying nitrogen by the factor 5.7. In the case of protein in the milk and the feces the factor used was 6.25. No attempt was made to separate and determine the amount of metabolic nitrogen of the feces. Carefully purified ether was used for determining ether extract in the bread and feces. The results obtained for the fat in the feces were not satisfactory in many cases, although the determinations were made in duplicate by the method generally followed and considered reliable. The fat in the milk was determined by the Adams gravimetric method. The ash was determined by combustion at a low temperature. The carbohydrates were estimated by subtracting the sum of the protein, ether extract, water, and ash from 100.

The determination of the ether extract in the feces necessarily involves an error, owing to the metabolic products present. Another source of error is in the protein determination. While the determination of the total nitrogen is satisfactory, the factor for converting this nitrogen into protein is not perfectly reliable, and in many cases is very unsatisfactory. It is well known that not all of the nitrogen of a food is in the form of proteid compounds. In the case of the food materials used in these experiments, namely, bread and milk, over 97 per cent of the total nitrogen is in the form of proteids, and the error from nonproteid nitrogen in the food is therefore small. In the case of the feces, however, the kinds, proportions, and composition of the nitrogenous ingredients are not well understood, and the estimate of "protein" is at best very crude. The errors involved in the determination of carbohydrates, by difference, are too well known to require discussion. Notwithstanding these imperfections of analytical methods, which are not peculiar to these investigations but are common to all similar experiments, the results obtained in determining moisture, ash, total nitrogen, and heat of combustion are believed to be reasonably accurate, and the deductions drawn from them are regarded as reliable.

The calorific value or heat of combustion of the various samples of food, feces, and urine was determined in the usual way by means of the bomb calorimeter. In the case of the milk and urine, weighed blocks of cellulose were employed to absorb the liquid. The absorption block was saturated, carefully dried, weighed, and again saturated with a weighed quantity of material. After drying at a temperature of 65° C. the block was burned in the calorimeter in the

usual way, a correction being made in the results for the heat of combustion of the block employed.

## DESCRIPTION OF SAMPLES OF FOOD MATERIALS.

In the milling of the hard spring wheat great care was taken to secure representative samples. As in the former work, the milling was carried on under the supervision of Mr. C. E. Foster, of Minneapolis, in one of the large flouring mills of that city. Two hundred pounds each of the three different kinds of flour were obtained from the mill. As soon as the samples were received at the laboratory smaller samples were drawn for analysis.

For the experiments with soft winter wheat difficulty was experienced in securing samples of soft-wheat flours that were comparable with the grades of flour used in former work with hard spring wheat. The samples of hard wheat used in 1899–1901 were exhaustively milled and very little flour was left in the bran and middlings.

The samples of soft wheat used in 1901–2 were, as is the custom with such wheats, less exhaustively milled and more flour was left in the offals. For this work sets of samples were obtained from two different milling companies, and in each case the different grades of flour were from a single lot of wheat.

A description of the different sorts of wheat used in the experiments, and of the different grades of flour and milling products made from them, is here given. These are the samples the analyses of which are reported in Table 1.

In addition to the various milling products mentioned, which are standard grades, other grades may be obtained by subdividing a grade or by mixing or blending two or more grades. Many of the flours which are placed upon the market are mixtures of two or more standard grades of flour.

No. 153. Hard Scotch Fife spring wheat, weighing 60 pounds per bushel; screened but not scoured. This wheat is representative of the hard spring wheat grown in the Northwestern wheat regions of the United States.

No. 154. Entire-wheat flour from hard spring wheat No. 153. This is the product obtained by removing a portion of the bran and grinding the remainder of the grain. It includes the germ and other parts of the offal products which are excluded from the patent grades of flour. This flour is coarser in texture and darker in color than the patent and clear grades. The presence of fine bran particles prevents perfect granulation. Such "entire-wheat" flour is sometimes called "pulverized graham" or "natural flour."

No. 155. Graham flour from hard spring wheat No. 153. This consists of the entire wheat kernel including bran, germ, and offal, ground into meal. Graham flour is practically wheat meal; no sieves or bolting cloths are employed in its manufacture, and coarse particles of bran, etc., may be observed in the flour.

No. 156. Straight patent flour from hard spring wheat No. 153. This includes the first and second patent grades and the first clear or bakers' grade of flour described below. Ordinarily about 72 per cent of the screened wheat is recovered as straight

No. 157. First patent flour from hard spring wheat No. 153. This is the highest grade of patent flour manufactured. Ordinarily about 56 per cent of the screened wheat is recovered as first patent flour, provided no straight flour is made. All of the patent grades of flour include the middlings which, by the former processes of milling, were not reduced to flour but were included in the offal products. The presence of the granular middlings gives a relatively high protein content to the patent grades of flour.

No. 158. Second patent flour from hard spring wheat No. 153. This is similar to first patent, but the bread made from it is a little darker in color and the gluten does not possess quite so high a power of expansion. The division of the flour into first, second, and straight patent grades is based entirely upon mechanical processes. In the higher grades of patent flour the gluten is distinctly different from that in the lower grades. The higher the grade of flour, the greater the power of expansion. It is this quality which enables the flour to absorb a large amount of water and as a result produce a large-sized loaf, and one of good physical properties.

No. 159. First clear flour from hard spring wheat No. 153. After the first and second grades of patent flour are removed in milling about 12 per cent of first clear grade is obtained. This grade has a high protein content, but the gluten is different in character from that of the first and second patent grades of flour. As already explained, when the first and second patent grades and the first clear grade are blended as one product, the blend is called straight or standard patent flour.

No. 160. Second clear or low-grade flour from hard spring wheat No. 153. After the removal of the first and second patent flours and the first clear flour about 5 per cent of the original wheat can be obtained as second clear or low-grade flour. This flour is much darker in color than the patent and first clear flours. It contains gluten, with a low power of expansion, and therefore is not so valuable for bread making as the higher grades of flour. Second clear flour is characterized by a high protein content, but for bread making this protein possesses poor physical properties.

No. 161. Red-dog flour from hard spring wheat. This is the lowest grade of flour manufactured. It is sometimes used for feeding animals, and occasionally for human food. It is obtained largely from the parts adjacent to the germ or embryo, and is characterized by a high protein content, this protein, however, having different properties from that in the higher grades of flour. It possesses but little power of expansion, and the bread made from this grade of flour is dark in color and poor in quality, at least as regards its physical properties. In the process of milling the wheat germ is not included in the higher grades of flour, because its protein is not composed of gliadin and glutenin. Furthermore, the germ ferments readily, and thus when present in flour has a tendency to render it unsound. Ordinarily from 5 to 8 per cent of the screened wheat is excluded as germ. This is utilized for the preparation of breakfast foods, for blending with other cereal food products, and for other purposes. Frequently, however, the wheat germ finds its way into the shorts and is used for cattle feed.

No. 162. Wheat shorts or middlings from hard spring wheat No. 153. About 11.5 to 12 per cent of the cleaned wheat is recovered as shorts, which consist of the fine bran that has been more or less completely pulverized. When the wheat germ is recovered with the shorts, the product is known as middlings. Such "middlings" must not be confused with the middlings obtained when wheat is milled by the old process. As previously stated, the material termed middlings in the old process is now reduced and recovered in the various grades of patent flour.

No. 163. Bran from hard spring wheat No. 153. This consists of the coarsely ground episperm or outer covering of the wheat kernel. Ordinarily from 13 to 15 per cent of the cleaned wheat is recovered as bran.

No. 164. Entire-wheat bread. This was made of the flour from which sample No. 154 was taken.

No. 182. Graham bread. This was made of the flour from which sample No. 155 was taken.

*Nos. 199 and 217. Straight patent flour bread. In making this bread flour was* used from which sample No. 156 was taken.

Nos. 165, 181, 198, and 216. Milk. Mixed milk, used in the digestion experiments.

No. 218. Cleaned soft winter wheat, from Goshen, Ind., prepared for milling, of good quality, and weighing 60 pounds per bushel. The sample analyzed was ground *in the laboratory in a Maercker mill.*

No. 221. Mixed-grade flour, ground from soft winter wheat No. 218, and consisting largely of straight flour with some lower grades and a little germ. As already explained, with exhaustive milling about 72 per cent of the screened wheat is recovered as straight flour, the grade most extensively used for bread making. If a lower percentage of wheat is recovered as flour, the sample is ranked, commercially, as a higher grade of patent flour because of its lighter color and other characteristic physical properties. This sample, No. 221, was not strictly a straight grade flour, but was more properly a blend.

No. 222. Entire-wheat flour, ground from soft winter wheat No. 218, after removing a small amount of bran. This sample was different from the entire wheat used in former work with hard wheat; it had more of the characteristics of graham. It was, however, *more finely pulverized than the graham flours used in the* experiments made in 1899–1901.

No. 267. Middlings obtained in the milling of the straight-grade flour No. 221, from soft winter wheat No. 218. Middlings include the fine particles of bran and germ, and, in case the wheat is not exhaustively milled, a small amount of the lowest grades of flour.

No. 268. Bran, from soft winter wheat No. 218.

No. 237. Soft winter wheat, of good quality from North Lansing, Mich., weighing 59 pounds per bushel, cleaned and prepared for milling.

No. 240. Straight grade or standard patent flour, milled from soft wheat No. 237. From the analysis of the flour and the appearance of the offals, it would seem that this flour contained somewhat less than 72 per cent of the original wheat. It should be classed as a high grade rather than as a straight-grade flour. It possessed good bread-making qualities, but required more thorough mixing and kneading than hard-wheat flours.

No. 238. Middlings, from soft winter wheat No. 237, obtained in milling flour No. 240.

No. 239. Bran, from soft winter wheat No. 237, obtained in milling flour No. 240.

No. 241. *Entire-wheat flour, prepared from soft winter wheat No. 237.*

No. 242. Graham flour, obtained from soft winter wheat No. 237.

No. 223. Mixed-grade flour bread. This was made of the flour from which sample No. 221 was taken.

No. 231. Entire-wheat flour bread. This was made of the flour from which sample No. *219* was taken.

No. 244. Straight patent flour bread. In making this bread flour was used from which sample No. 240 was taken.

No. 251. Entire-wheat flour bread. This bread was made of the flour from which sample No. 241 was taken.

No. 260. Graham-flour bread. The graham flour used was the lot from which sample No. 242 was taken.

## COMPOSITION OF SAMPLES OF FOOD MATERIALS.

In Table 1, which follows, are given the results of the analyses of the wheat samples, of the flours and other products made from the

wheat, of the bread made from the flours, and of the milk consumed in the digestion experiments.

TABLE 1.—*Composition of wheats, flours, and offals, and of bread, and milk used in digestion experiments with hard and soft wheat breads.*

| Sample No. | Whence obtained. | Water. | Protein.[a] | Fat. | Carbohydrates. | Ash. | Heat of combustion per gram, determined. |
|---|---|---|---|---|---|---|---|
| | Hard wheat: | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Calories.* |
| 153 | Wheat | 10.41 | 15.50 | 2.28 | 69.88 | 1.93 | 4.023 |
| 154 | Entire-wheat flour | 13.51 | 13.72 | 1.69 | 70.10 | .98 | 3.877 |
| 155 | Graham flour | 13.21 | 14.21 | 2.01 | 68.56 | 2.01 | 3.971 |
| 156 | Straight patent flour | 12.38 | 13.60 | 1.30 | 72.04 | .68 | 3.861 |
| 157 | First patent flour | 12.16 | 13.31 | 1.21 | 72.93 | .39 | 3.960 |
| 158 | Second patent flour | 12.09 | 13.05 | 1.37 | 73.03 | .46 | 3.904 |
| 159 | First clear flour | 11.92 | 17.73 | 1.98 | 67.37 | 1.00 | 4.072 |
| 160 | Second clear flour | 10.40 | 20.00 | 3.17 | 64.24 | 2.19 | 4.112 |
| 161 | Red dog flour | 10.26 | 21.83 | 6.10 | 57.72 | 4.09 | 4.430 |
| 162 | Middlings | 10.17 | 18.64 | 6.04 | 59.72 | 5.43 | 4.314 |
| 163 | Bran | 11.47 | 17.10 | 4.23 | 59.89 | 7.31 | 4.187 |
| | Bread made from— | | | | | | |
| 164 | Entire-wheat flour | 40.97 | 9.32 | .19 | 48.75 | .77 | 2.535 |
| 182 | Graham flour | 42.68 | 9.54 | .29 | 46.10 | 1.39 | 2.495 |
| 199 | Straight patent flour | 38.77 | 9.63 | .04 | 51.06 | .50 | 2.594 |
| 217 | Do | 37.37 | 9.74 | .26 | 52.12 | .51 | 2.647 |
| | Soft wheat: | | | | | | |
| 218 | Wheat from Indiana | 8.09 | 13.16 | 1.52 | 75.38 | 1.85 | 4.090 |
| 219 | Entire-wheat flour | 9.60 | 12.80 | 1.54 | 74.40 | 1.66 | 4.020 |
| 221 | Mixed grade flour | 10.30 | 12.30 | .93 | 75.94 | .53 | 4.010 |
| 237 | Wheat from Michigan | 10.25 | 12.34 | 1.35 | 74.23 | 1.83 | 4.000 |
| 238 | Middlings | 7.86 | 17.91 | 5.18 | 65.09 | 3.96 | 4.256 |
| 239 | Bran | 8.74 | 14.96 | 4.41 | 65.78 | 6.11 | 4.108 |
| 240 | Straight patent flour | 10.97 | 10.92 | .50 | 77.15 | .46 | 3.799 |
| 241 | Entire-wheat flour | 11.01 | 12.01 | 1.53 | 74.17 | 1.28 | 3.860 |
| 242 | Graham flour | 11.23 | 12.24 | 1.41 | 73.27 | 1.85 | 3.906 |
| 267 | Middlings | 9.76 | 18.34 | 4.65 | 64.05 | 3.20 | .......... |
| 268 | Bran | 10.94 | 16.72 | 4.42 | 61.20 | 6.72 | .......... |
| | Bread made from— | | | | | | |
| 223 | Mixed grade flour | 39.56 | 8.01 | .60 | 51.32 | .51 | 2.710 |
| 231 | Entire-wheat flour | 39.50 | 8.53 | 1.02 | 49.49 | 1.46 | 2.640 |
| 244 | Straight patent flour | 36.87 | 7.59 | .38 | 54.67 | .49 | 2.610 |
| 251 | Entire-wheat flour | 37.62 | 8.33 | 1.08 | 51.70 | 1.27 | 2.690 |
| 260 | Graham flour | 38.12 | 8.36 | .87 | 51.20 | 1.45 | 2.620 |
| 165 | Milk, composite sample | 87.81 | 3.25 | 3.80 | 4.34 | .80 | .700 |
| 181 | .....do | 87.27 | 3.13 | 4.00 | 4.71 | .89 | .746 |
| 198 | .....do | 87.59 | 3.04 | 3.82 | 4.81 | .74 | .729 |
| 216 | .....do | 87.14 | 3.38 | 4.15 | 4.57 | .76 | .744 |
| 224 | .....do | 87.00 | 3.31 | 4.38 | 4.52 | .79 | .780 |
| 232 | .....do | 86.56 | 3.32 | 4.67 | 4.68 | .77 | .813 |
| 243 | .....do | 87.34 | 2.99 | 4.09 | 4.81 | .77 | .742 |
| 258 | .....do | 87.67 | 3.00 | 3.85 | 4.75 | .73 | .735 |
| 259 | .....do | 86.50 | 3.25 | 4.45 | 5.03 | .77 | .777 |

[a] In all samples except milk, protein is N×5.70; in milk it is N×6.25.

The hard Scotch Fife spring wheat selected for the experiments (sample No. 153) was characterized by a very high protein content, namely, 15.5 per cent. In an earlier publication of this Department showing the average composition of a large number of American feeding stuffs[a] the protein content of wheat is given as 11.9 per cent. The highest percentage of protein there recorded is 17.2 per cent and the lowest 8.1 per cent. It will be observed that the wheat from which these flour samples were obtained contained nearly this maximum amount of proteid material. In the investigations with hard wheat previously reported,[b] the wheat employed contained 12.65 per cent protein. The average amount of protein in the same variety of wheat

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. No. 11, p. 17.
[b] U. S. Dept. Agr., Office of Experiment Stations Bul. No. 101.

is found to vary materially from year to year, depending among other things upon the amount of rainfall and the climatic conditions under which the wheat has matured. The wheat crop produced in the northwestern United States in 1900 was unusually rich in protein. The rainfall and climatic conditions seemed to be particularly favorable for producing wheat and other grains with a high nitrogen content. While the wheat employed in this investigation contained somewhat more protein than is found in average wheat, in the author's opinion the percentage is no greater than in average wheat grown in the northwestern United States in 1900. All of the flour samples from this wheat were relatively richer in protein than those in similar investigations with hard wheat in 1898–99, owing to the high nitrogen content of the wheat. The differences in the protein content of the several grades of flour ground from the wheat were comparatively small.

There was a higher percentage of fat in the middlings than in the bran, owing to the presence of the germ in the former. Red-dog flour is the richest, as regards both fat and protein, of the products ground from the wheat. In the case of the patent and clear grades of flour, the heat of combustion as determined was found to agree closely with the heat of combustion obtained by calculation, using the usual factors, namely, 9.3 calories per gram[a] for fat, 5.9 for protein, and 4.2 for carbohydrates. As pointed out in a previous report,[b] the percentage of ash in the various products of wheat was lowest in the first patent flour and highest in the red-dog flour. Each grade of flour, beginning with the first patent, was found to contain proportionally more ash than the preceding grade. In fact, as noted previously, the grade of flour can be determined from the amount of ash present. In the analyses reported above the ash content is greater than in the samples employed in the earlier work with hard wheat in this laboratory. There appears to be a close relationship between the amounts of ash and protein present in flour and other milled products of wheat, any material increase in protein being accompanied by a corresponding increase in mineral matter. This has often been attributed to the phosphorus associated with the proteids. Late work of Osborne[c] indicates that the total amount of phosphorus in wheat proteids is too small to account for the increase in mineral matter just alluded to.

The distribution of the nitrogen and ash constituents of the wheat berry has been frequently studied, and it is interesting to note some comparatively recent American work on the subject, particularly as the investigations were made with wheats grown in the United States, which are therefore directly comparable with the wheats used in the investigation reported in this bulletin.

Mrs. Ellen H. Richards and Miss Lottie A. Bragg[d] studied the distri-

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 101, p. 12. [b] Ib., p. 9.
[c] Connecticut State Station Rpt. 1900, p. 464. [d] Tech. Quart., 3 (1890), p. 246.

bution of nitrogen and phosphorus in winter and spring wheat and their milling products, in both cases the milling products having been ground from the same lots of wheat. The results obtained are shown in the following table, which includes also values for protein obtained by multiplying the figures for nitrogen by 6.25:

TABLE 2.—*Nitrogen and phosphorus in wheat and its milling products.*

| Milling products. | Water. | Phosphorus. | Nitrogen. | Protein (N × 6.25). |
|---|---|---|---|---|
| St. Louis winter wheat: | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Whole wheat | 12.85 | 0.262 | 1.87 | 11.7 |
| Royal patent flour | 13.37 | .051 | 1.39 | 8.7 |
| Extra fancy flour | 12.51 | .100 | 1.78 | 11.1 |
| Low-grade flour | 11.94 | .100 | 2.08 | 13.0 |
| Middlings | 11.21 | .225 | 2.73 | 17.1 |
| Bran | 12.15 | .828 | 2.62 | 16.4 |
| Minnesota spring wheat: | | | | |
| Whole wheat | 11.09 | .230 | 2.24 | 14.0 |
| Patent flour | 12.29 | .050 | 2.10 | 13.1 |
| Bakers' flour | 12.14 | .091 | 2.40 | 15.0 |
| Shorts | 11.27 | .560 | 2.78 | 17.4 |
| Bran | 11.23 | .830 | 2.55 | 15.9 |

The figures in the table indicate that, while a larger part of the protein is recovered in the flour than is the case with the phosphorus, there is, nevertheless, a parallelism in the proportion of protein and phosphorus in the different milling products.

At the Arkansas Experiment Station, Teller[a] made a very thorough and detailed study of the ash constituents of a sample of locally grown medium hard winter wheat and its milling products. In milling 3,000 pounds of uncleaned wheat, 1.83 per cent was recovered as screenings and 0.33 per cent as tailings, the percentage of milling products being as follows: Patent flour 25.80, straight flour 42, low-grade flour 3.87, dust room contents 1.17, ship stuff 1.13, and bran 23.80. The loss of material in grinding—that is, the material unaccounted for—was therefore only 0.07 per cent.

The principal ash constituents and the sulphur and nitrogen in the whole wheat and the different milling products were as follows:

TABLE 3.—*Ash constituents and nitrogen of winter wheat and its milling products.*

| Milling products. | Total ash.[b] | In total ash. | | | | | | Sulphur. | Nitrogen. |
|---|---|---|---|---|---|---|---|---|---|
| | | Silica. | Ferric oxid. | Potash. | Lime. | Magnesia. | Phosphoric acid. | | |
| | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* |
| Wheat | 1.62 | 1.04 | 0.27 | 29.70 | 3.10 | 13.23 | 52.14 | 0.18 | 1.96 |
| Patent flour | .31 | 2.33 | .47 | 38.50 | 5.59 | 4.39 | 48.05 | .09 | 1.54 |
| Straight flour | .40 | 1.28 | .26 | 36.31 | 5.65 | 6.44 | 49.32 | .10 | 1.75 |
| Low-grade flour | .70 | .50 | .25 | 32.27 | 4.51 | 9.33 | 53.10 | .16 | 2.13 |
| Dust room material | 2.50 | 1.34 | .30 | 30.85 | 3.53 | 12.90 | 49.94 | .15 | 2.17 |
| Ship stuff | 3.08 | .49 | .37 | 28.03 | 2.80 | 13.27 | 54.62 | .17 | 2.78 |
| Bran | 5.25 | .97 | .27 | 28.19 | 2.50 | 14.76 | 52.81 | .21 | 2.73 |

[a] Arkansas Station Bul. 42, pts. 1, 2.

[b] This sum includes values which are given for alumina, chlorin, zinc, and sulphur trioxid, which are not quoted in the table. The author regards the values for sulphur present in the different materials as more reliable than those for sulphur trioxid in the ash, owing to a probable volatilization of sulphur in burning to obtain the ash. The other constituents omitted are not of much importance, the alumina and zinc being accidentally present.

Teller points out that about 87.5 per cent of the entire phosphoric acid, 78.5 per cent of the potash, and 37.5 per cent of the nitrogen present in the wheat berry are recovered in the milling products ordinarily used as cattle feeds. As will be seen from the above table, the percentage of phosphoric acid increases as the grade of flour decreases, being least in the patent flour and greatest in low-grade flour, the proportion present in the latter being greater than in any of the milling products except ship stuff; in other words, as shown by these figures, the phosphoric acid content, generally speaking, increases in passing from the center of the wheat berry to the outer layer, the inner portion yielding the fine flour and the outer portion the bran. The table also shows that in the various milling products the proportion of nitrogen (and hence that of protein, since the latter is computed by multiplying nitrogen by a constant factor) varies in practically the same way as the phosphorus.

The parallelism between protein and phosphorus, which was spoken of above, is borne out by the analytical data quoted, though it does not necessarily follow that the phosphorus present occurs in the true proteids.

As a whole, it has been the aim in the experiments conducted at the University of Minnesota to include standard types and varieties of hard and soft wheat flours, milled under different conditions. The differences in the percentages of flour recovered from the wheat used necessarily make slight differences in the composition and characteristics of the grades of flour obtained. The soft wheat products were of different character from the samples of similar products from hard wheat. The hard wheats had been exhaustively milled, as is the usual custom, in one of the large mills of Minneapolis, while the soft winter wheats were ground by mills of smaller capacity using somewhat different milling systems, and, as is the general commercial practice, were less exhaustively milled.

In general, the flours from soft wheat were somewhat similar to, though not in every respect like those from, hard wheat, because of the differences in the kinds of wheat used and percentages of flour recovered. The graham flour contained the largest percentage of protein, fat, and ash, while the patent grades of flour contained the smallest amounts of these ingredients. A noticeable difference in the mechanical composition of the three grades of soft wheat flour was observed. With the process of milling followed, some granular middlings were left in the offals which would have been recovered in the straight and other grades of flour with more exhaustive milling. This results in a straight-grade flour containing slightly less protein than the product of exhaustive milling, as the granular middlings are rich in this nutrient. The particles or granules of the graham flour were

much larger than those of either the entire-wheat or the straight-grade flour. The comparative sizes of granules from graham, entire-wheat, and straight-grade flours ground from soft wheat are shown in the micro-photographs reproduced in Plate I, figs. 1 and 2, and Plate II, fig. 1, p. 48.

## COMPOSITION OF FECES AND URINE OBTAINED IN DIGESTION EXPERIMENTS.

The composition of the dry matter of the feces from the digestion experiments is given in Table 4, while Table 5 records the amount, specific gravity, and percentage of nitrogen of the urine.

A description of the samples of feces and urine follows:

Nos. 178, 199, 180, 195, 196, 197, 213, 214, and 215 represent the feces which were obtained in the digestion experiments with hard spring wheat products.

Nos. 225, 226, 227, 233, 234, 235, 245, 246, 247, 252, 253, 254, 261, 262, and 263, the feces which were obtained in the digestion experiments of 1901-2 with soft winter wheat.

Nos. 166-177, 183-194, and 200-212, the urine from the digestion experiments with hard spring wheat products.

Nos. 228, 229, 230, 236, 237, 238, 248, 249, 250, 255, 256, 257, 264, 265, and 266, the urine obtained in the experiments with soft winter wheat.

TABLE 4.—*Composition of dry matter of feces from digestion experiments with hard and soft wheat breads.*

| Sample No. | Whence obtained. | Protein (N×6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion per gram determined. |
|---|---|---|---|---|---|---|
| | Experiments with hard wheat: | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Calories.* |
| 178 | Experiment No. 242 | 30.25 | 12.26 | 34.42 | 23.07 | 4.638 |
| 179 | Experiment No. 243 | 28.37 | 7.45 | 35.37 | 28.81 | 4.070 |
| 180 | Experiment No. 244 | 25.00 | 7.44 | 41.35 | 26.21 | 4.351 |
| 195 | Experiment No. 245 | 23.25 | 8.70 | 50.16 | 17.89 | 4.415 |
| 196 | Experiment No. 246 | 23.31 | 5.61 | 47.59 | 23.49 | 3.960 |
| 197 | Experiment No. 247 | 21.67 | 6.41 | 50.48 | 21.44 | 4.170 |
| 213 | Experiment No. 248 | 29.94 | 17.46 | 25.02 | 27.58 | 4.720 |
| 214 | Experiment No. 249 | 28.56 | 11.44 | 26.42 | 33.58 | 4.265 |
| 215 | Experiment No. 250 | 23.94 | 9.30 | 36.47 | 30.29 | 4.654 |
| | Experiments with soft wheat: | | | | | |
| 225 | Experiment No. 309 | 14.10 | 17.04 | 45.15 | 23.71 | 5.030 |
| 226 | Experiment No. 310 | 21.83 | 15.84 | 38.92 | 23.41 | 5.300 |
| 227 | Experiment No. 311 | 26.75 | 9.10 | 39.40 | 24.75 | 4.400 |
| 233 | Experiment No. 312 | 14.31 | 5.36 | 60.48 | 19.85 | 4.340 |
| 234 | Experiment No. 313 | 16.76 | 10.32 | 55.98 | 16.94 | 4.420 |
| 235 | Experiment No. 314 | 20.06 | 4.32 | 56.51 | 19.11 | 4.160 |
| 245 | Experiment No. 315 | 22.61 | 8.58 | 43.99 | 24.82 | 5.050 |
| 246 | Experiment No. 316 | 23.13 | 13.13 | 38.92 | 24.82 | 5.160 |
| 247 | Experiment No. 317 | 25.34 | 15.26 | 32.59 | 26.81 | 5.360 |
| 252 | Experiment No. 318 | 17.94 | 5.31 | 56.28 | 20.47 | 4.290 |
| 253 | Experiment No. 319 | 21.00 | 11.65 | 46.38 | 20.97 | 4.410 |
| 254 | Experiment No. 320 | 18.67 | 6.00 | 51.76 | 23.57 | 3.990 |
| 261 | Experiment No. 321 | 19.50 | 6.44 | 57.06 | 17.00 | 4.220 |
| 262 | Experiment No. 322 | 17.86 | 13.98 | 51.14 | 17.02 | 4.470 |
| 263 | Experiment No. 323 | 19.13 | 8.25 | 52.68 | 19.94 | 4.170 |

TABLE 5.—*Amount, specific gravity, and nitrogen of urine from digestion experiments with hard and soft wheat breads.*

| Sample No. | Subject No. | Whence obtained. | Total amount voided. | Specific gravity. | Nitrogen. |
|---|---|---|---|---|---|
| | | Experiments with hard wheat: | | | |
| | | Experiment No. 242— | *Grams.* | | *Per cent.* |
| 166 | 1 | First day | 1,368.0 | 1.026 | 1.58 |
| 169 | 1 | Second day | 1,350.0 | 1.023 | 1.45 |
| 172 | 1 | Third day | 1,463.5 | 1.027 | 1.63 |
| 175 | 1 | Fourth day | 1,326.0 | 1.029 | 1.74 |
| | | Experiment No. 243— | | | |
| 167 | 2 | First day | 1,805.0 | 1.016 | .88 |
| 170 | 2 | Second day | 2,112.0 | 1.015 | .95 |
| 173 | 2 | Third day | 2,298.0 | 1.015 | 1.00 |
| 176 | 2 | Fourth day | 2,248.0 | 1.017 | .98 |
| | | Experiment No. 244— | | | |
| 168 | 3 | First day | 1,991.0 | 1.020 | 1.35 |
| 171 | 3 | Second day | 1,720.0 | 1.021 | 1.41 |
| 174 | 3 | Third day | 1,679.0 | 1.025 | 1.72 |
| 177 | 3 | Fourth day | 1,947.0 | 1.028 | 1.45 |
| | | Experiment No. 245— | | | |
| 183 | 1 | First day | 1,270.0 | 1.030 | 1.82 |
| 186 | 1 | Second day | 1,210.0 | 1.030 | 1.79 |
| 189 | 1 | Third day | 1,212.0 | 1.030 | 1.84 |
| 192 | 1 | Fourth day | 1,102.0 | 1.028 | 1.88 |
| | | Experiment No. 246— | | | |
| 184 | 2 | First day | 1,943.0 | 1.015 | 1.03 |
| 187 | 2 | Second day | 1,732.0 | 1.015 | 1.01 |
| 190 | 2 | Third day | 2,188.0 | 1.015 | .95 |
| 193 | 2 | Fourth day | 2,368.0 | 1.014 | .99 |
| | | Experiment No. 247— | | | |
| 185 | 3 | First day | 1,851.0 | 1.024 | 1.39 |
| 188 | 3 | Second day | 1,581.0 | 1.025 | 1.72 |
| 191 | 3 | Third day | 1,614.5 | 1.027 | 1.75 |
| 194 | 3 | Fourth day | 1,338.0 | 1.027 | 1.94 |
| | | Experiment No. 248— | | | |
| 200 | 1 | First day | 1,124.0 | 1.027 | 1.77 |
| 204 | 1 | Second day | 1,077.0 | 1.031 | 2.10 |
| 207 | 1 | Third day | 1,068.0 | 1.030 | 1.90 |
| 210 | 1 | Fourth day | 1,110.0 | 1.029 | 2.04 |
| | | Experiment No. 249— | | | |
| 201 | 2 | First day | 1,943.0 | 1.014 | 1.02 |
| 205 | 2 | Second day | 1,698.0 | 1.015 | 1.00 |
| 208 | 2 | Third day | 2,182.0 | 1.015 | .97 |
| 211 | 2 | Fourth day | 2,023.0 | 1.014 | .97 |
| | | Experiment No. 250— | | | |
| 203 | 3 | First day | 1,123.0 | 1.028 | 1.82 |
| 206 | 3 | Second day | 1,242.0 | 1.026 | 1.81 |
| 209 | 3 | Third day | 1,601.0 | 1.022 | 1.56 |
| 212 | 3 | Fourth day | 2,463.0 | 1.016 | 1.07 |
| | | Experiments with soft wheat: | | | |
| 228 | 1 | Experiment No. 309 | 6,023.1 | 1.016 | 1.10 |
| 229 | 2 | Experiment No. 310 | 4,296.2 | 1.020 | 1.50 |
| 230 | 3 | Experiment No. 311 | 4,486.2 | 1.019 | 1.31 |
| 236 | 1 | Experiment No. 312 | 5,652.9 | 1.019 | 1.21 |
| 237 | 2 | Experiment No. 313 | 5,201.7 | 1.020 | 1.41 |
| 238 | 3 | Experiment No. 314 | 4,115.6 | 1.022 | 1.48 |
| 248 | 1 | Experiment No. 315 | 7,317.4 | 1.016 | 1.19 |
| 249 | 2 | Experiment No. 316 | 6,556.6 | 1.019 | 1.41 |
| 250 | 3 | Experiment No. 317 | 4,747.6 | 1.020 | 1.39 |
| 255 | 1 | Experiment No. 318 | 7,889.1 | 1.016 | 1.07 |
| 256 | 2 | Experiment No. 319 | 6,910.1 | 1.020 | 1.47 |
| 257 | 3 | Experiment No. 320 | 5,476.6 | 1.021 | 1.61 |
| 264 | 1 | Experiment No. 321 | 5,210.1 | 1.020 | 1.41 |
| 265 | 2 | Experiment No. 322 | 4,532.0 | 1.020 | 1.16 |
| 266 | 3 | Experiment No. 323 | 4,508.8 | 1.022 | 1.80 |

## EXPERIMENTAL METHODS.

The methods followed in all of the experiments here reported are practically identical with those described in detail in the previous publication[a] already referred to, and need only be briefly outlined.

The bread from the different sorts of flour was eaten with milk; the amount of either was not limited, but the quantities eaten at each meal were recorded. The separations of the feces were made by means of

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 101.

charcoal taken with a meal of bread and milk, which gives feces of a characteristic color and consistency. The digestibility of the nutrients of the diet as a whole was taken as the difference between the amounts in the food and those in the feces, no attempt being made to determine the metabolic products of the feces.[a]

In order to compute the digestibility of the nutrients of the bread alone, it was assumed that 97 per cent of the protein, 95 per cent of the fat, and 98 per cent of the carbohydrates of milk were digested. The undigested nutrients of the milk as calculated by the use of these factors subtracted from the nutrients of the total feces give the estimated undigested nutrients from bread, which, subtracted from the total nutrients of the bread, give the digestible nutrients in bread. The latter, divided by the total nutrients in the bread, give the coefficients of digestibility of bread alone.

The values used for the digestibility of the nutrients of milk have been deduced from the results of a large number of digestion experiments with milk. Even if, in the experiments here reported, the digestibility of the milk nutrients varied from these assumed coefficients, the figures for the digestibility of the nutrients of the different kinds of bread are still strictly comparable because the same factors for milk were used in all cases.

As has been already explained,[b] the energy of the estimated feces from bread alone was computed by proportion from the energy of the total feces. The ratio of the heat of combustion of the bread feces as computed by factors to the actual energy was assumed to be the same as the ratio of the computed energy of total feces to the heat of combustion as determined.

Although the energy of the urine was determined, in the calculation of the availability of the energy of the total food and of the bread alone, it was assumed, for the sake of uniformity with experiments previously reported, that 1.25 calories of energy would appear in the urine for every gram of digestible protein in the total food or in the bread alone. For the sake of making an approximate estimate of the available energy in those experiments where the digestibility of the bread fat could not be computed, it was assumed that 90 per cent of

[a]It should be observed that the results thus obtained do not represent actual digestibility. The true digestibility could be found by subtracting from the ingredients of the food the corresponding ingredients of the feces that come only from undigested portions of the food. But no satisfactory method has been found for separating these from the metabolic products in the feces, which consist largely of the residues of the digestive juices that have not been reabsorbed. These latter represent the cost of digestion as expressed in terms of food ingredients. What the results of these experiments do represent, therefore, is the proportions of the food, or of the several ingredients, that are available to the body for purposes other than digestion itself. In accordance with common usage, however, the term digestibility, which indicates the apparent digestibility, has been employed here; the term availability is sometimes used to express the same idea.

[b]U. S. Dept. Agr., Office of Experiment Stations Bul. 101, p. 22.

the fat of the bread was digestible. The results thus found would probably be below rather than above what was actually the case.

As in the preceding experiments, the balance of income and outgo of nitrogen was learned by determining the daily amounts ingested in the food and excreted in the urine and feces. In the experiments with soft winter wheat in 1901–2 determinations were also made of the phosphoric acid in the samples of food, feces, and urine. Such data, however, are reserved for further study.

The particular difference between the digestion experiments given here and those formerly reported is in the length of the experimental period, this being four days long here and only two in the earlier experiments. The longer experimental period is believed to be preferable, because it is generally considered that there is less danger of error due to uncontrollable factors that may vitiate the results in a short digestion period.

As is well known, the results obtained from a digestion experiment are not absolute, but only relative. But inasmuch as in the digestion experiments reported in this bulletin the object is to determine the relative rather than the absolute digestibility of three different kinds of bread, it is believed that the results obtained are satisfactory for this purpose, because whatever error may be introduced in one experiment is introduced alike in all of any given series, since the conditions were kept uniform throughout the series. While the results of a single digestion experiment are open to criticism, the results obtained from a series of experiments are much less so and are of value in determining whether one food is more digestible than another under similar experimental conditions. Hence in discussing the results obtained from these digestion experiments they are considered in relation to one another rather than alone.

## DETAILS OF THE DIGESTION EXPERIMENTS WITH BREAD FROM DIFFERENT GRADES OF HARD SPRING WHEAT FLOUR.

The details of the digestion experiments with hard wheat products are given in the following pages. Nine digestion experiments, each of four days' (or twelve meals') duration were made with three different subjects. In every case the diet consisted of bread and milk, and all of the experiments were conducted in the same manner, except that bread made from a different kind of flour was used in each series. In making the bread no shortening or milk was used, but simply yeast, flour, salt, and water.

The subjects were university students who spent from three to four hours each day at light muscular work out of doors. All had served as subjects in former digestion experiments and were thoroughly familiar with the requirements of such work.

The experiments were practically made in triplicate—that is, the same kind of an experiment was made with each of three subjects at

the same time. The order in which they were conducted was as follows: The first series of experiments (with entire-wheat bread) extended from April 17 to April 20, inclusive; the second series (with graham bread) from April 23 to April 26, inclusive; and the third series (with bread from standard patent flour) from May 1 to May 4, inclusive. The experiments were taken up in this order because of the difficulty experienced in previous experiments with a graham bread and milk diet. It was believed that the investigation could be conducted to better advantage by having the graham bread experiment between the others, rather than at the beginning or close of the series. The four days' diet of graham bread and milk caused a slight irritation of the digestive tract and a slight attack of gastritis with two of the subjects.

The following tables, Nos. 6 to 14, and the accompanying data show the kind of food consumed, the subject experimented upon, the body weight at the beginning and at the close of the experiment, and the date and duration. Then follow statistics of the total nutrients in the food and the feces, and the heat of combustion of each, and after each of the tables statistics are given of the income and outgo of nitrogen during the experiment.

## DIGESTION EXPERIMENT NO. 242.

*Kind of food.*—Milk, and bread made from entire-wheat flour.

*Subject.*—University student No. 1, 22 years old, employed about four hours per day at manual labor.

*Weight.*—At the beginning of the experiment, 168 pounds; at the close, 168 pounds.

*Duration.*—Four days, with twelve meals, beginning with breakfast April 17, 1901.

TABLE 6.—*Results of digestion experiment No. 242.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 164 | Bread | 3,550.0 | 330.9 | 6.7 | 1,730.7 | 27.3 | 8,998 |
| 165 | Milk | 9,950.0 | 323.4 | 378.1 | 431.8 | 79.6 | 6,965 |
| | Total | ........ | 654.3 | 384.8 | 2,162.5 | 106.9 | 15,963 |
| 178 | Feces (water free) | 214.0 | 64.7 | 26.2 | 73.7 | 49.4 | 992 |
| | Estimated feces from food other than bread | ........ | 9.7 | ........ | 8.6 | ........ | ........ |
| | Estimated feces from bread | ........ | 55.0 | ........ | 65.1 | ........ | ........ |
| | Total amount digested | ........ | 589.6 | 358.6 | 2,088.8 | 57.5 | 14,971 |
| | Estimated digestible nutrients in bread | ........ | 275.9 | ........ | 1,665.6 | ........ | ........ |
| | Coefficients of digestibility of total food | *Per cent* ........ | *Per cent.* 90.1 | *Per cent.* 93.2 | *Per cent.* 96.6 | *Per cent.* 58.8 | *Per cent.* 93.8 |
| | Estimated coefficients of digestibility of bread | ........ | 83.4 | ........ | 96.2 | ........ | a 93.0 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | ........ | ........ | ........ | ........ | ........ | 88.2 |
| | In bread alone | ........ | ........ | ........ | ........ | ........ | a 89.1 |

a Estimated on the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 5,508 grams urine, containing 88.42 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 27.47 grams; outgo in urine, 22.10 grams and in feces, 2.59 grams, implying a gain of 2.78 grams nitrogen, corresponding to 17.4 grams protein.

## DIGESTION EXPERIMENT NO. 243.

*Kind of food.*—Milk, and bread made from entire-wheat flour.

*Subject.*—University student No. 2, 22 years old, employed about four hours per day at manual labor.

*Weight.*—At the beginning of the experiment, 156 pounds; at the close, 155 pounds.

*Duration.*—Four days, with twelve meals, beginning with breakfast April 17, 1901.

TABLE 7.—*Results of digestion experiment No. 243.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbo-hydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 164 | Bread | 3,101.0 | 289.0 | 5.9 | 1,511.8 | 23.9 | 7,860 |
| 165 | Milk | 12,310.0 | 400.1 | 467.8 | 534.3 | 98.5 | 8,617 |
| | Total | | 689.1 | 473.7 | 2,046.1 | 122.4 | 16,477 |
| 179 | Feces (water free) | 180.0 | 51.1 | 13.4 | 63.7 | 51.9 | 733 |
| | Estimated feces from food other than bread | | 12.0 | | 10.7 | | |
| | Estimated feces from bread | | 39.1 | | 53.0 | | |
| | Total amount digested | | 638.0 | 460.3 | 1,982.4 | 70.5 | 15,744 |
| | Estimated digestible nutrients in bread | | 249.9 | | 1,458.8 | | |
| | Coefficients of digestibility of total food | *Per cent.* | *Per cent.* 92.6 | *Per cent.* 97.2 | *Per cent.* 96.9 | *Per cent.* 57.6 | *Per cent.* 95.6 |
| | Estimated coefficients of digestibility of bread | | 86.5 | | 96.5 | | [a] 90.4 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | | | | | | 90.7 |
| | In bread alone | | | | | | [a] 90.0 |

[a] Estimated on the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 8,463 grams urine, containing 80.95 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 28.68 grams; outgo in urine, 20.24 grams, and in feces, 2.09 grams, implying a gain of 6.35 grams nitrogen, corresponding to 39.7 grams protein.

## DIGESTION EXPERIMENT NO. 244.

*Kind of food.*—Milk, and bread made from entire-wheat flour.

*Subject.*—University student No. 3, 24 years old, employed about four hours per day at manual labor.

*Weight.*—At the beginning of the experiment, 161 pounds; at the close, 160 pounds.

*Duration.*—Four days, with twelve meals, beginning with breakfast April 17, 1901.

TABLE 8.—*Results of digestion experiment No. 244.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 164 | Bread | 3,760.0 | 350.4 | 7.1 | 1,833.1 | 28.9 | 9,530 |
| 165 | Milk | 14,843.0 | 482.4 | 564.0 | 644.2 | 118.8 | 10,390 |
| | Total | | 832.8 | 571.1 | 2,477.3 | 147.7 | 19,920 |
| 180 | Feces (water free) | 215.1 | 53.8 | 16.0 | 88.9 | 56.4 | 936 |
| | Estimated feces from food other than bread | | 14.5 | | 12.9 | | |
| | Estimated feces from bread | | 39.3 | | 76.0 | | |
| | Total amount digested | | 779.0 | 555.1 | 2,388.4 | 91.3 | 18,984 |
| | Estimated digestible nutrients in bread | | 311.1 | | 1,757.1 | | |
| | Coefficients of digestibility of total food | *Per cent.* | *Per cent.* 93.5 | *Per cent.* 97.2 | *Per cent.* 96.4 | *Per cent.* 61.8 | *Per cent.* 95.3 |
| | Estimated coefficients of digestibility of bread | | 88.8 | | 95.9 | | [a] 94.3 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | | | | | | 90.4 |
| | In bread alone | | | | | | [a] 90.2 |

[a] Estimated on the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 7,337 grams urine, containing 108.24 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 34.66 grams; outgo in urine, 27.06 grams, and in feces, 2.15 grams, implying a gain of 5.45 grams nitrogen, corresponding to 34.1 grams protein.

## DIGESTION EXPERIMENT NO. 245.

*Kind of food.*—Milk, and bread made from graham flour.

*Subject.*—University student No. 1.

*Weight.*—At the beginning of the experiment, 168 pounds; at the close, 167 pounds.

*Duration.*—Four days, with twelve meals, beginning with breakfast April 23, 1901.

TABLE 9.—*Results of digestion experiment No. 245.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories* |
| 182 | Bread | 3,342.0 | 318.8 | 9.7 | 1,540.7 | 46.5 | 8,337 |
| 181 | Milk | 10,207.0 | 319.5 | 408.3 | 480.8 | 90.8 | 7,614 |
| | Total | .......... | 638.3 | 418.0 | 2,021.5 | 137.3 | 15,951 |
| 195 | Feces (water free) | 300.1 | 69.8 | 26.1 | 150.5 | 53.7 | 1,325 |
| | Estimated feces from food other than bread | .......... | 9.6 | 20.4 | 9.6 | .......... | 302 |
| | Estimated feces from bread | .......... | 60.2 | 5.7 | 140.9 | .......... | 1,023 |
| | Total amount digested | .......... | 568.5 | 391.9 | 1,871.0 | 83.6 | 14,626 |
| | Estimated digestible nutrients in bread | .......... | 258.6 | 4.0 | 1,399.8 | .......... | 7,314 |
| | *Coefficients of digestibility of* total food | *Per cent* .......... | *Per cent.* 89.1 | *Per cent.* 93.8 | *Per cent.* 92.6 | *Per cent.* 60.9 | *Per cent.* 91.7 |
| | Estimated coefficients of digestibility of bread | .......... | 81.1 | 41.2 | 90.9 | .......... | 87.7 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | .......... | .......... | .......... | .......... | .......... | 87.2 |
| | In bread alone | .......... | .......... | .......... | .......... | .......... | 83.9 |

During this experiment the subject eliminated 4,794 grams urine, containing 87.79 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 26.74 grams; outgo in urine, 21.95 grams, and in feces 3.79 grams, implying a gain of 1 gram nitrogen, corresponding to 6.3 grams protein.

## DIGESTION EXPERIMENT NO. 246.

*Kind of food.*—Milk, and bread made from graham flour.

*Subject.*—University student No. 2.

*Weight.*—At the beginning of the experiment, 154 pounds; at the close, 152.7 pounds.

*Duration.*—Four days, with twelve meals, beginning with breakfast April 23, 1901.

TABLE 10.—*Results of digestion experiment No. 246.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 182 | Bread | 2,855.0 | 272.4 | 8.3 | 1,316.2 | 39.7 | 7,123 |
| 181 | Milk | 10,568.0 | 330.8 | 422.7 | 497.8 | 94.1 | 7,883 |
| | Total | .......... | 603.2 | 431.0 | 1,814.0 | 133.8 | 15,006 |
| 196 | Feces (water free) | 259.0 | 60.4 | 14.5 | 123.3 | 60.8 | 1,026 |
| | Estimated feces from food other than bread | .......... | 9.9 | .......... | 10.0 | .......... | .......... |
| | Estimated feces from bread | .......... | 50.5 | .......... | 113.3 | .......... | .......... |
| | Total amount digested | .......... | 542.8 | 416.5 | 1,690.7 | 73.0 | 13,980 |
| | Estimated digestible nutrients in bread | .......... | 221.9 | .......... | 1,202.9 | .......... | .......... |

TABLE 10.—*Results of digestion experiment No. 246*—Continued.

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Coefficients of digestibility of total food | *Per cent.* | *Per cent.* 90.0 | *Per cent.* 96.6 | *Per cent.* 93.2 | *Per cent.* 54.6 | *Per cent.* 93.2 |
| | Estimated coefficients of digestibility of bread | | 81.5 | | 91.4 | | [a] 88.9 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | | | | | | 88.6 |
| | In bread alone | | | | | | [a] 85.1 |

[a] Estimated on the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 8,231 grams urine, containing 81.73 grams nitrogen. The average nitrogen balance per day was, therefore, as follows: Income in food, 25.16 grams; outgo in urine, 20.43 grams, and in feces, 2.94 grams, implying a gain of 1.79 grams nitrogen, corresponding to 11.2 grams protein.

## DIGESTION EXPERIMENT NO. 247.

*Kind of food.*—Milk, and bread made from graham flour.

*Subject.*—University student No. 3.

*Weight.*—At the beginning of the experiment, 161 pounds; at the close, 157 pounds.

*Duration.*—Four days, with twelve meals, beginning with breakfast April 23, 1901.

TABLE 11.—*Results of digestion experiment No. 247.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 182 | Bread | 3,440.0 | 328.2 | 10.0 | 1,585.9 | 47.8 | 8,583 |
| 181 | Milk | 12,475.0 | 390.5 | 499.0 | 587.6 | 111.0 | 9,306 |
| | Total | | 718.7 | 509.0 | 2,173.5 | 158.8 | 17,889 |
| 197 | Feces (water free) | 267.7 | 58.0 | 17.2 | 135.1 | 57.4 | 1,116 |
| | Estimated feces from food other than bread | | 11.7 | | 11.7 | | |
| | Estimated feces from bread | | 46.3 | | 123.4 | | |
| | Total amount digested | | 660.7 | 491.8 | 2,038.4 | 101.4 | 16,773 |
| | Estimated digestible nutrients in bread | | 281.9 | | 1,462.5 | | |
| | Coefficients of digestibility of total food | *Per cent.* | *Per cent.* 91.9 | *Per cent.* 96.6 | *Per cent.* 93.8 | *Per cent.* 63.9 | *Per cent.* 93.8 |
| | Estimated coefficients of digestibility of bread | | 85.9 | | 92.2 | | [a] 90.3 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | | | | | | 89.2 |
| | In bread alone | | | | | | [a] 86.2 |

[a] Estimated on the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 6,385 grams urine, containing 107.13 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 30.01 grams; outgo in urine, 26.78 grams, and in feces, 2.32 grams, implying a gain of 0.91 grams nitrogen, corresponding to 5.7 grams protein.

### DIGESTION EXPERIMENT NO. 248.

*Kind of food.*—Milk, and bread made from straight patent flour.

*Subject.*—University student No. 1.

*Weight.*—At the beginning of experiment, 164 pounds; at the close, 164 pounds.

*Duration.*—Four days, with twelve meals, beginning with breakfast May 1, 1901.

TABLE 12.—*Results of digestion experiment No. 248.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 199 | Bread | 2,575.0 | 248.0 | 1.0 | 1,314.9 | 12.9 | 6,680 |
| 198 | Milk | 10,583.0 | 321.7 | 404.3 | 509.0 | 78.3 | 7,715 |
| | Total | .......... | 569.7 | 405.3 | 1,823.9 | 91.2 | 14,395 |
| 213 | Feces (water free) | 152.0 | 45.5 | 26.5 | 38.0 | 41.9 | 717 |
| | Estimated feces from food other than bread | .......... | 9.6 | 20.2 | 10.2 | .......... | 309 |
| | Estimated feces from bread | .......... | 35.9 | .......... | 27.8 | .......... | .......... |
| | *Total amount digested* | .......... | 524.2 | 378.8 | 1,785.9 | 49.3 | 13,678 |
| | Estimated digestible nutrients in bread | .......... | 212.1 | .......... | 1,287.1 | .......... | .......... |
| | Coefficients of digestibility of total food | *Per cent.* .......... | *Per cent.* 92.0 | *Per cent.* 93.5 | *Per cent.* 97.9 | *Per cent.* 54.1 | *Per cent.* 95.0 |
| | Estimated coefficients of digestibility of bread | .......... | 85.5 | .......... | 97.9 | .......... | *a* 94.8 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | .......... | .......... | .......... | .......... | .......... | 90.5 |
| | In bread alone | .......... | .......... | .......... | .......... | .......... | *a* 90.9 |

*a* Estimated on the assumption that 90 per cent of the fat in bread is digestible.

During this experiment the subject eliminated 4,378 grams urine, containing 85.44 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 23.79 grams; outgo in urine, 21.38 grams, and in feces, 1.82 grams, implying a gain of 0.59 gram nitrogen, corresponding to 3.7 grams protein.

### DIGESTION EXPERIMENT NO. 249.

*Kind of food.*—Milk, and bread made from straight patent flour.

*Subject.*—University student No. 2.

*Weight.*—At the beginning of the experiment, 152 pounds; at the close, 151½ pounds.

*Duration.*—Four days, with twelve meals, beginning with breakfast May 1, 1901.

TABLE 13.—*Results of digestion experiment No. 249.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 199 | Bread | 2,790.0 | 268.7 | 1.2 | 1,424.6 | 13.9 | 7,237 |
| 198 | Milk | 11,717.0 | 356.2 | 447.6 | 563.6 | 86.7 | 8,542 |
| | Total | | 624.9 | 448.8 | 1,988.2 | 100.6 | 15,779 |
| 214 | Feces (water free) | 146.8 | 41.9 | 16.8 | 38.8 | 49.3 | 626 |
| | Estimated feces from food other than bread | | 10.7 | | 11.3 | | |
| | Estimated feces from bread | | 31.2 | | 27.5 | | |
| | Total amount digested | | 583.0 | 432.0 | 1,949.4 | 51.3 | 15,153 |
| | Estimated digestible nutrients in bread | | 237.5 | | 1,397.1 | | |
| | Coefficients of digestibility of total food | *Per cent.* | *Per cent.* 93.3 | *Per cent.* 96.3 | *Per cent.* 98.1 | *Per cent.* 51.0 | *Per cent.* 96.0 |
| | Estimated coefficients of digestibility of bread | | 88.4 | | 98.1 | | [a]95.5 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | | | | | | 91.4 |
| | In bread alone | | | | | | [a]91.4 |

[a] Estimated on the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 7,846 grams urine, containing 77.52 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 26.05 grams; outgo in urine, 19.38 grams, and in feces, 1.68 grams, implying a gain of 4.99 grams nitrogen, corresponding to 31.2 grams protein.

## DIGESTION EXPERIMENT NO. 250.

*Kind of food.*—Milk, and bread made from straight patent flour.

*Subject.*—University student No. 3.

*Weight.*—At the beginning of the experiment, 152 pounds; at the close, 155 pounds.

*Duration.*—Four days, with twelve meals, beginning with breakfast May 1, 1901.

TABLE 14.—*Results of digestion experiment No. 250.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 217 | Bread | 3,080.0 | 300.0 | 8.0 | 1,605.3 | 15.7 | 8,152 |
| 216 | Milk | 13,055.0 | 441.3 | 541.8 | 596.6 | 99.2 | 9,713 |
| | Total | | 741.3 | 549.8 | 2,201.9 | 114.9 | 17,865 |
| 215 | Feces (water free) | 167.0 | 40.0 | 15.5 | 60.9 | 50.6 | 777 |
| | Estimated feces from food other than bread | | 13.2 | | 11.9 | | |
| | Estimated feces from bread | | 26.8 | | 49.0 | | |
| | Total amount digested | | 701.3 | 534.3 | 2,141.0 | 64.3 | 17,088 |
| | Estimated digestible nutrients in bread | | 273.2 | | 1,556.3 | | |

TABLE 14.—*Results of digestion experiment No. 250*—Continued.

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Coefficients of digestibility of total food | *Per cent.* | *Per cent.* 94.6 | *Per cent.* 97.2 | *Per cent.* 97.2 | *Per cent.* 56.0 | *Per cent.* 95.7 |
| | Estimated coefficients of digestibility of bread | | 91.1 | | 97.0 | | [a] 94.5 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | | | | | | 90.8 |
| | In bread alone | | | | | | [a] 90.3 |

[a] Estimated on the assumption that 90 per cent of the fat in the bread is digestible.

*During this experiment the subject eliminated 6,439 grams urine*, containing 94.25 grams nitrogen. The average nitrogen balance per day was therefore as follows: Income in food, 30.76 grams; outgo in urine, 23.56 grams, and in feces, 1.60 grams, implying a gain of 5.60 grams nitrogen, corresponding to 35.0 grams protein.

## SUMMARY OF RESULTS OBTAINED WITH HARD SPRING WHEAT PRODUCTS.

The following tables summarize the results of the digestion experiments with hard spring wheat products reported in the foregoing pages. The results are given for the whole ration in Table 15 and computed for the different sorts of bread alone in Table 16. For purposes of comparison, the results obtained in previous experiments in this laboratory are also included, as well as the average digestibility of the different kinds of bread as shown by the result of all the experiments.

TABLE 15.—*Summary of digestion experiments with hard spring wheat; digestibility of nutrients and availability of energy of total food.*

| Experiment No. | Subject No. | Kind of food. | Protein. | Fat. | Carbohydrates. | Energy. |
|---|---|---|---|---|---|---|
| | | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 242 | 1 | Milk and entire wheat bread | 90.1 | 93.2 | 96.6 | 89.2 |
| 243 | 2 | .....do | 92.6 | 97.2 | 96.9 | 90.7 |
| 244 | 3 | .....do | 93.5 | 97.2 | 96.4 | 90.4 |
| | | Average of 3 | 92.1 | 95.9 | 96.6 | 90.1 |
| | | Average of 3 (1899-1900) | 89.7 | 91.7 | 95.1 | 88.5 |
| | | Average of 6 | 90.9 | 93.8 | 95.8 | 89.3 |
| 245 | 1 | Milk and graham bread | 89.1 | 93.8 | 92.6 | 87.2 |
| 246 | 2 | .....do | 90.0 | 96.6 | 93.2 | 88.6 |
| 247 | 3 | .....do | 91.9 | 96.6 | 93.8 | 89.2 |
| | | Average of 3 | 90.3 | 95.7 | 93.2 | 88.3 |
| | | Average of 3 (1899-1900) | 88.2 | 91.1 | 91.1 | 86.0 |
| | | Average of 6 | 89.3 | 93.4 | 92.2 | 87.2 |
| 248 | 1 | Milk and white bread (standard patent) | 92.0 | 93.5 | 97.9 | 90.5 |
| 249 | 2 | .....do | 93.3 | 96.3 | 98.1 | 91.4 |
| 250 | 3 | .....do | 94.6 | 97.2 | 97.2 | 90.8 |
| | | Average of 3 | 93.3 | 95.7 | 97.7 | 90.9 |
| | | Average of 3 (1899-1900) | 91.4 | 92.4 | 97.6 | 90.5 |
| | | Average of 6 | 92.4 | 94.5 | 97.7 | 90.6 |

ABLE 16.—*Summary of digestion experiments with hard spring wheat; digestibility of nutrients and availability of energy of bread alone.*

| xperi-ment No. | Subject No. | Kind of food. | Protein. | Carbo-hydrates. | Energy. |
|---|---|---|---|---|---|
| | | | *Per cent.* | *Per cent.* | *Per cent.* |
| 242 | 1 | Entire wheat bread | 83.4 | 96.2 | 89.1 |
| 243 | 2 | .....do | 86.5 | 96.5 | 90.0 |
| 244 | 3 | .....do | 88.8 | 95.9 | 90.2 |
| | | Average of 3 | 86.2 | 96.2 | 89.8 |
| | | Average of 3 (1899–1900) | 80.4 | 94.1 | 85.5 |
| | | Average of 6 | 83.3 | 95.1 | 87.6 |
| 245 | 1 | Graham bread | 81.1 | 90.9 | 83.9 |
| 246 | 2 | .....do | 81.5 | 91.4 | 85.1 |
| 247 | 3 | .....do | 85.9 | 92.2 | 86.2 |
| | | Average of 3 | 82.8 | 91.5 | 85.1 |
| | | Average of 3 (1899–1900) | 77.6 | 88.4 | 80.7 |
| | | Average of 6 | 80.2 | 90.0 | 82.9 |
| 248 | 1 | White bread (standard patent) | 85.5 | 97.9 | 90.9 |
| 249 | 2 | .....do | 88.4 | 98.1 | 91.4 |
| 250 | 3 | .....do | 91.1 | 97.0 | 90.3 |
| | | Average of 3 | 88.3 | 97.7 | 90.9 |
| | | Average of 3 (1899–1900) | 85.3 | 97.5 | 90.1 |
| | | Average of 6 | 86.8 | 97.6 | 90.5 |

It will be observed that the average coefficients of digestibility of ie protein and carbohydrates and of the available energy in the ıtion consisting of milk and bread made from straight patent flour round from hard spring wheat were larger than in the rations of milk nd entire-wheat bread or milk and graham bread from the same lot f wheat. Considering the calculated results for bread alone, in the xperiments here reported it appears that in the graham bread the verage digestibility of the protein is 82.8 per cent; of the carbohy-rates, 91.5 per cent, and the available energy is 85.1 per cent. The igestion coefficients for the graham bread are lower than for either ie entire-wheat bread or the straight patent flour bread. In the case f the bread from entire-wheat flour 86.2 per cent of the protein was igested, and in the straight patent flour bread 88.3 per cent, while 6.2 per cent of the carbohydrates in the entire-wheat flour bread and 7.7 per cent of those in the bread from the straight patent flour were ound to be digestible.

An examination of the tables also shows in each of the series a range f from 4 to nearly 6 per cent in the digestion coefficients of each of ie nutrients. This is probably due to differences in the digestive owers of the three subjects. Thus, for example, subject No. 3 igested the bread made from straight patent flour, entire-wheat our, and graham flour more completely than either subject No. 1 or No. 2. While individual differences are observed in the three series f experiments, in every case it appears that each subject digested ie nutrients in the straight patent flour bread more completely than ie nutrients in either the entire-wheat bread or the graham bread.

Hence the results for the average digestibility in the different series of experiments are strictly comparable.

The tables also compare the results of the experiments reported in this bulletin and those formerly reported.[a] It will be observed that although the digestion coefficients are somewhat larger in the experiments here reported than in those of 1899–1900, there is a general similarity of results. In both series the nutrients of the bread from standard patent flour are the most and those of graham the least digestible, the entire-wheat flour bread being between the two. These experiments are regarded as strictly comparable. Considering the two years' investigations as a whole, six subjects were employed and eighteen separate digestion experiments were made.

Table 16 gives the average digestibility of the nutrients and availability of the energy in the three kinds of bread as shown by the results of the two series. It is believed that these figures show, with a fair degree of accuracy, the comparative digestibility of the protein and carbohydrates and availability of energy in bread made from the three kinds of flour when milled from the same lot of hard spring wheat and consumed under similar conditions. The results, considered as a whole, show that the protein in the straight patent flour bread is 6.6 per cent more digestible than that of the graham bread, while the carbohydrates are 5.6 per cent more digestible. The amount of available energy in the straight-flour bread is also greater by 7.5 per cent than that in the graham bread.

In Table 17 the total and digestible protein and carbohydrates and total and available energy in the three different kinds of flour as milled are given. These values for digestible nutrients and available energy were obtained by multiplying the percentage of total nutrients and energy by the coefficients given in Table 17.

TABLE 17.—*Percentages of digestible protein and carbohydrates, and available energy in entire-wheat, graham, and straight patent flours as milled.*

| Grade of flour from hard spring wheat. | Protein (N×5.70). | | Carbohydrates. | | Energy per gram. | |
|---|---|---|---|---|---|---|
| | Total. | Digestible. | Total. | Digestible. | Total. | Available. |
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Straight patent | 13.60 | 12.01 | 72.04 | 70.31 | 3.861 | 3.510 |
| Entire wheat | 13.72 | 11.83 | 70.09 | 67.43 | 3.877 | 3.481 |
| Graham | 14.21 | 11.77 | 68.55 | 62.62 | 3.971 | 3.379 |

There was a somewhat larger amount of digestible protein in the straight patent flour than in either the graham or entire-wheat flour. In the straight patent flour there was 70.31 per cent of digestible carbohydrates, in the entire-wheat flour 67.43 per cent, and in the

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 101, p. 33.

graham flour 62.62 per cent; that is, the carbohydrates of the straight patent flour were much more digestible than those of either the entire wheat or graham flour. The amount of available energy of the straight patent flour is also larger than that of either the graham or entire-wheat flour.

On comparing the figures in this table with those previously reported[a] it will be observed that the results for protein here given are higher. This is due to two facts already pointed out, namely, that the percentage of protein in the wheat employed in these experiments was higher, and the coefficients of digestibility were larger. The significance of the results, however, is the same in both cases. Briefly stated, the results of all of the experiments with hard spring wheat show that the digestible protein and carbohydrates, as well as the amount of available energy, are greater in the standard patent flour than in either the graham or entire-wheat flour.

No marked variations in the balance of income and outgo of nitrogen were observed in the different periods except such as were due to differences in the amounts consumed. In other words, judged by the data regarding the metabolism of nitrogen, the three sorts of breads served the body equally well.

The results of these experiments confirm those of earlier work with hard-wheat flours, and show that when breads made from straight patent flour, entire-wheat flour, and graham flour, milled from the same lot of hard spring wheat, are fed under uniform experimental conditions to men, there is a larger amount of digestible protein and carbohydrates and available energy in the patent flour than in either the entire-wheat or graham flour, although judged by composition the graham flour contains the most and the patent flour the least total protein. The greater digestibility of the protein and carbohydrates of the patent flour is regarded as due in part at least to the fineness of division of the flour particles, or, in other words, to the fact that a considerable portion of the nutrients in the graham and entire-wheat flours are present in comparatively large particles, which resist the action of the digestive fluids and so escape digestion. It has also been suggested that the cell walls in the layer of the grain directly under the bran are more resistant to digestive juices than the walls of cells in the interior of the kernel (see pp. 48, 49). Thus while there is actually somewhat more protein, pound for pound, in graham or entire-wheat than in patent flour, the body obtains less protein and energy from the coarser than it does from the finer flour, and whatever is gained in composition by adding the bran or germ is offset by the loss in digestibility.

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[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 101, p. 33.

## DETAILS OF THE DIGESTION EXPERIMENTS WITH BREAD FROM DIFFERENT GRADES OF SOFT WINTER WHEAT FLOUR.

In order to determine whether the results obtained with bread from hard-wheat flours would be the same with flours from wheat of a different character, fifteen digestion experiments were made with bread from graham, entire-wheat, and standard patent flours milled from soft winter wheat. The results of these experiments are reported on the following pages.

Two sets of experiments were made. In one set, comprising the first six of the following experiments, the flours used were prepared from the same lot of Indiana soft winter wheat by a milling company of Goshen, Ind. Only two kinds of flour were used in these six experiments, one being a standard patent grade similar to but not quite the same as the same grade of flour used in the experiments with hard wheat; the other was a so-called entire-wheat flour, but was somewhat coarser than this grade of flour prepared from hard wheat. In the second set of experiments three grades of flours were used, all ground from the same lot of Michigan soft winter wheat by a milling company of North Lansing, Mich.

The experiments were made by the same methods as were followed in earlier work with hard-wheat flours. The experiment proper was preceded by a preliminary meal of bread and milk, charcoal being used to mark the separation of the feces. The experimental period continued three days in the experiments with the Indiana flours, and four days with the Michigan flours. The subjects were young men in good health, designated as Nos. 1, 2, and 3. They were employed at farm labor, office, and university work. One subject, No. 1, had been employed in the digestion work of 1900 and 1901 as subject No. 3. The subjects were allowed a diet of bread and milk, unrestricted as to amount, the quantities consumed at each meal being carefully weighed. The different series of experiments in which graham, entire-wheat, and straight-grade flours were used were alike in all respects except as regards the bread. The four days' diet of milk and graham bread proved to be rather laxative. It was observed that the subjects who were employed at the severest labor had a decided preference for the bread made from the straight and mixed grade flours, while the one employed at office and university work did not have so pronounced a preference. In no case was the graham bread preferred.

Tables 18 to 32 record the data of the several digestion experiments.

### DIGESTION EXPERIMENT NO. 309.

*Kind of food.*—Milk, and bread made from straight-grade flour.

*Subject.*—Man No. 1; age, 25 years; employed at office work.

*Weight.*—At the beginning of the experiment, 161.25 pounds; at the close, 162 pounds.

*Duration.*—Three days, with nine meals, beginning with breakfast April 9, 1902.

TABLE 18.—*Results of digestion experiment No. 309.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 223 | Bread | 2,950.0 | 236.3 | 17.7 | 1,513.9 | 15.0 | 7,994 |
| 224 | Milk | 9,850.0 | 326.0 | 431.4 | 445.2 | 77.8 | 7,683 |
| | Total | .......... | 562.3 | 449.1 | 1,959.1 | 92.8 | 15,677 |
| 225 | Feces (water free) | 166.0 | 23.4 | 28.3 | 74.9 | 39.4 | 835 |
| | Estimated feces from food other than bread | .......... | 9.8 | 21.6 | 8.9 | .......... | 347 |
| | Estimated feces from bread | .......... | 13.6 | 6.7 | 66.0 | .......... | 488 |
| | Total amount digested | .......... | 538.9 | 420.8 | 1,884.2 | 53.4 | 14,842 |
| | Estimated digestible nutrients in bread | .......... | 222.7 | 11.0 | 1,447.9 | .......... | 7,506 |
| | Coefficients of digestibility of total food | *Per cent.* | *Per cent.* 95.8 | *Per cent.* 93.7 | *Per cent.* 96.2 | *Per cent.* 57.5 | *Per cent.* 94.7 |
| | Estimated coefficients of digestibility of bread | .......... | 94.2 | 62.1 | 95.6 | .......... | 93.9 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | .......... | .......... | .......... | .......... | .......... | 90.4 |
| | In bread alone | .......... | .......... | .......... | .......... | .......... | 90.4 |

During this experiment the subject eliminated 6,023 grams urine, containing 66.25 grams nitrogen. The nitrogen balance per day was therefore as follows: Income in food, 31.20 grams; outgo in urine, 22.08 grams, and in feces, 1.25 grams, implying a gain of 7.87 grams nitrogen, corresponding to 49.2 grams protein.

## DIGESTION EXPERIMENT NO. 310.

*Kind of food.*—Milk, and bread made from straight-grade flour.

*Subject.*—Man No. 2; age, 25 years; university student; employed at average farm labor four hours per day.

*Weight.*—At the beginning and close of the experiment, 163.75 pounds.

*Duration.*—Three days, with nine meals, beginning with breakfast April 9, 1902.

TABLE 19.—*Results of digestion experiment No. 310.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 223 | Bread | 2,860.0 | 229.0 | 17.2 | 1,467.7 | 14.6 | 7,751 |
| 224 | Milk | 7,850.0 | 259.8 | 343.8 | 354.8 | 62.0 | 6,123 |
| | Total | .......... | 488.8 | 361.0 | 1,822.5 | 76.6 | 13,874 |
| 226 | Feces (water free) | 147.0 | 32.1 | 23.3 | 57.2 | 34.4 | 779 |
| | Estimated feces from food other than bread | .......... | 7.8 | 17.2 | 7.1 | .......... | 287 |
| | Estimated feces from bread | .......... | 24.3 | 6.1 | 50.1 | .......... | 492 |

TABLE 19.—*Results of digestion experiment No. 310*—Continued.

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| | Total amount digested | | 456.7 | 337.7 | 1,765.3 | 42.2 | 13,095 |
| | Estimated digestible nutrients in bread | | 204.7 | 11.0 | 1,417.6 | | 7,259 |
| | Coefficients of digestibility of total food | *Per cent.* | *Per cent.* 93.4 | *Per cent.* 93.5 | *Per cent.* 96.9 | *Per cent.* 55.1 | *Per cent.* 94.4 |
| | Estimated coefficients of digestibility of bread | | 89.4 | 64.4 | 96.6 | | 93.6 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | | | | | | 90.3 |
| | In bread alone | | | | | | 90.4 |

During this experiment the subject eliminated 4,296 grams urine, containing 64.61 grams nitrogen. The nitrogen balance per day was therefore as follows: Income in food, 27.25 grams; outgo in urine, 21.54 grams, and in feces, 1.71 grams, implying a gain of 4 grams nitrogen, corresponding to 25 grams protein.

## DIGESTION EXPERIMENT NO. 311.

*Kind of food.*—Milk, and bread made from straight-grade flour.

*Subject.*—Man No. 3; 21 years of age, employed at average farm labor.

*Weight.*—At the beginning of the experiment, 151.75 pounds; at the close, 150.5 pounds.

*Duration.*—Three days, with nine meals, beginning with breakfast April 9, 1902.

TABLE 20.—*Results of digestion experiment No. 311.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 223 | Bread | 2,572.0 | 206.0 | 15.4 | 1,319.9 | 13.1 | 6,970 |
| 224 | Milk | 6,771.0 | 224.1 | 296.6 | 306.1 | 53.5 | 5,281 |
| | Total | | 430.1 | 312.0 | 1,626.0 | 66.6 | 12,251 |
| 227 | Feces (water free) | 156.0 | 41.7 | 14.2 | 61.5 | 38.6 | 686 |
| | Estimated feces from food other than bread | | 6.7 | | 6.1 | | |
| | Estimated feces from bread | | 35.0 | | 55.4 | | |
| | Total amount digested | | 388.4 | 297.8 | 1,564.5 | 28.0 | 11,565 |
| | Estimated digestible nutrients in bread | | 171.0 | | 1,264.5 | | |
| | Coefficients of digestibility of total food | *Per cent.* | *Per cent.* 90.3 | *Per cent.* 95.5 | *Per cent.* 96.2 | *Per cent.* 42.0 | *Per cent.* 94.4 |
| | Estimated coefficients of digestibility of bread | | 83.0 | | 95.8 | | [a]93.5 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | | | | | | 90.4 |
| | In bread alone | | | | | | [a]90.4 |

[a] Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 4,486 grams urine, containing 58.77 grams nitrogen. The nitrogen balance per day was therefore as follows: Income in food 24 grams; outgo in urine 19.59 grams, and in feces 223 grams, implying a gain of 2.18 grams nitrogen, corresponding to 13.6 grams protein.

### DIGESTION EXPERIMENT NO. 312.

*Kind of food.*—Milk, and bread made from finely ground graham or entire-wheat flour.

*Subject.*—Man No. 1, as in experiment No. 309.

*Weight.*—At the beginning of the experiment 163.75 pounds; at the close 164 pounds.

*Duration.*—Three days with nine meals, beginning with breakfast April 14, 1902.

TABLE 21.—*Results of digestion experiment No. 312.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 231 | Bread | 3,110.0 | 265.3 | 31.7 | 1,539.1 | 45.4 | 8,210 |
| 232 | Milk | 9,500.0 | 315.4 | 443.6 | 444.6 | 73.1 | 7,723 |
| | Total | | 580.7 | 475.3 | 1,983.7 | 118.5 | 15,933 |
| 233 | Feces (water free) | 260.3 | 37.3 | 13.9 | 157.4 | 51.7 | 1,130 |
| | Estimated feces from food other than bread | | 9.4 | | 8.9 | | |
| | Estimated feces from bread | | 27.9 | | 148.5 | | |
| | Total amount digested | | 543.4 | 461.4 | 1,826.3 | 66.8 | 14,803 |
| | Estimated digestible nutrients in bread | | 237.4 | | 1,390.6 | | |
| | Coefficients of digestibility of total food | *Per cent.* | *Per cent.* 93.6 | *Per cent.* 97.1 | *Per cent.* 92.1 | *Per cent.* 56.4 | *Per cent.* 92.9 |
| | Estimated coefficients of digestibility of bread | | 89.5 | | 90.3 | | [a] 90.2 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | | | | | | 88.6 |
| | In bread alone | | | | | | [a] 85.2 |

[a] Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 5,201.7 grams urine, containing 68.23 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 32.34 grams; outgo in urine, 22.74 grams, and in feces, 1.95 grams, implying a gain of 7.65 grams nitrogen, corresponding to 47.8 grams protein.

### DIGESTION EXPERIMENT NO. 313.

*Kind of food.*—Milk, and bread made from finely ground graham or entire-wheat flour.

*Subject.*—Man No. 2, as in experiment No. 310.

*Weight.*—At the beginning of the experiment, 164.5 pounds; at the close, 164.75 pounds.

*Duration.*—Three days, with nine meals, beginning with breakfast April 14, 1902.

TABLE 22.—*Results of digestion experiment No. 313.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbo-hydrates. | Ash. | Heat of combus-tion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 231 | Bread | 3,070.0 | 261.9 | 31.3 | 1,519.3 | 44.8 | 8,105 |
| 232 | Milk | 9,770.0 | 324.4 | 456.3 | 457.2 | 75.2 | 7,943 |
| | Total | | 586.3 | 487.6 | 1,976.5 | 120.0 | 16,048 |
| 234 | Feces (water free) | 294.0 | 49.3 | 30.3 | 164.6 | 49.8 | 1,299 |
| | Estimated feces from food other *than bread* | | 9.7 | 22.8 | 9.2 | | 319 |
| | Estimated feces from bread | | 39.6 | 7.5 | 155.4 | | 980 |
| | Total amount digested | | 537.0 | 457.3 | 1,811.9 | 70.2 | 14,749 |
| | Estimated digestible nutrients in bread | | 222.3 | 23.8 | 1,363.9 | | 7,125 |
| | Coefficients of digestibility of total food | *Per cent.* | *Per cent.* 91.6 | *Per cent.* 93.8 | *Per cent.* 91.7 | *Per cent.* 58.5 | *Per cent.* 91.9 |
| | Estimated coefficients of digestibility of bread | | 84.9 | 76.0 | 89.8 | | 87.9 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | | | | | | 87.7 |
| | *In bread alone* | | | | | | 84.5 |

During this experiment the subject eliminated 5,201.7 grams urine, containing 73.35 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 32.62 grams; outgo in urine, 24.45 grams, and in feces, 2.60 grams, implying a gain of 5.57 grams nitrogen, corresponding to 34.8 grams protein.

## DIGESTION EXPERIMENT NO. 314.

*Kind of food.*—Milk, and bread made from finely ground graham or entire-wheat flour.

*Subject.*—Man No. 3, as in experiment No. 311.

*Weight.*—At the beginning of the experiment, 150.5 pounds; at the close, 151 pounds.

*Duration.*—Three days, with nine meals, beginning with breakfast April 14, 1902.

TABLE 23.—*Results of digestion experiment No. 314.*

| Sample No. | | Weight of *material.* | Protein. | Fat. | Carbo-hydrates. | Ash. | Heat of combus-tion. |
|---|---|---|---|---|---|---|---|
| | | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| | Food consumed: | | | | | | |
| 231 | Bread | 2,670.0 | 227.7 | 27.2 | 1,321.4 | 39.0 | 7,049 |
| 232 | Milk | 8,000.0 | 265.6 | 373.6 | 374.4 | 61.6 | 6,504 |
| | Total | | 493.3 | 400.8 | 1,695.8 | 100.6 | 13,553 |
| 235 | Feces (water free) | 275.0 | 55.2 | 11.9 | 155.4 | 52.6 | 1,144 |
| | Estimated feces from food other than bread | | 8.0 | | 7.5 | | |
| | Estimated feces from bread | | 47.2 | | 147.9 | | |

TABLE 23.—*Results of digestion experiment No. 314*—Continued.

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| | Total amount digested | .......... | 438.1 | 388.9 | 1,540.4 | 48.0 | 12,409 |
| | Estimated digestible nutrients in bread | .......... | 180.5 | .......... | 1,173.5 | .......... | .......... |
| | Coefficients of digestibility of total food | *Per cent.* .......... | *Per cent.* 88.8 | *Per cent.* 97.0 | *Per cent.* 90.8 | *Per cent.* 47.7 | *Per cent.* 91.6 |
| | Estimated coefficients of digestibility of bread | .......... | 79.3 | .......... | 88.8 | .......... | [a]86.1 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | .......... | .......... | .......... | .......... | .......... | 87.5 |
| | In bread alone | .......... | .......... | .......... | .......... | .......... | [a]82.9 |

[a] Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 4,115.6 grams urine, containing 60.91 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 27.48 grams; outgo in urine, 20.30 grams, and in feces, 2.94 grams, implying a gain of 4.24 grams nitrogen, corresponding to 26.5 grams protein.

## DIGESTION EXPERIMENT NO. 315.

*Kind of food.*—Milk, and bread made from straight flour.

*Subject.*—Man No. 1, as in experiment No. 309.

*Weight.*—At the beginning and close of the experiment, 166 pounds.

*Duration.*—Four days, with twelve meals, beginning with breakfast April 28, 1902.

TABLE 24.—*Results of digestion experiment No. 315.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 244 | Bread | 3,615.0 | 274.4 | 13.7 | 1,976.3 | 17.7 | 9,435 |
| 243 | Milk | 11,750.0 | 351.3 | 480.6 | 565.2 | 90.5 | 8,719 |
| | Total | .......... | 625.7 | 494.3 | 2,541.5 | 108.2 | 18,154 |
| 245 | Feces (water free) | 132.0 | 29.8 | 11.3 | 58.1 | 32.8 | 667 |
| | Estimated feces from food other than bread | .......... | 10.5 | .......... | 11.3 | .......... | .......... |
| | Estimated feces from bread | .......... | 19.3 | .......... | 46.8 | .......... | .......... |
| | Total amount digested | .......... | 595.9 | 483.0 | 2,483.4 | 75.4 | 17,487 |
| | Estimated digestible nutrients in bread | .......... | 255.1 | .......... | 1,929.5 | .......... | .......... |
| | Coefficients of digestibility of total food | *Per cent.* .......... | *Per cent.* 95.2 | *Per cent.* 97.7 | *Per cent.* 97.7 | *Per cent.* 69.7 | *Per cent.* 96.3 |
| | Estimated coefficient of digestibility of bread | .......... | 93.0 | .......... | 97.6 | .......... | [a]97.3 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | .......... | .......... | .......... | .......... | .......... | 92.2 |
| | In bread alone | .......... | .......... | .......... | .......... | .......... | [a]93.4 |

[a] Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 7,317.4 grams urine, containing 87.08 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 26.09 grams; outgo in urine, 21.77 grams, and in feces, 1.19 grams, implying a gain of 3.13 grams nitrogen, corresponding to 19.6 grams protein.

## DIGESTION EXPERIMENT NO. 316.

*Kind of food.*—Milk, and bread made from straight flour.

*Subject.*—Man No. 2, as in experiment No. 310.

*Weight.*—At the beginning and close of the experiment, 166 pounds.

*Duration.*—Four days, with twelve meals, beginning with breakfast April 28, 1902.

TABLE 25.—*Results of digestion experiment No. 316.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| | Bread | 3,480.0 | 264.1 | 13.2 | 1,902.3 | 17.0 | 9,082 |
| 244 | Milk | 12,730.0 | 380.6 | 520.6 | 612.3 | 98.0 | 9,445 |
| 243 | Total | | 644.7 | 533.8 | 2,514.6 | 115.0 | 18,527 |
| 246 | Feces (water free) | 113.6 | 26.1 | 14.8 | 44.0 | 28.0 | 583 |
| | Estimated feces from food other than bread | | 11.4 | | 12.3 | | |
| | Estimated feces from bread | | 14.7 | | 31.7 | | |
| | Total amount digested | | 618.6 | 519.0 | 2,470.6 | 87.0 | 17,944 |
| | Estimated digestible nutrients in bread | | 249.4 | | 1,870.6 | | |
| | Coefficients of digestibility of total food | *Per cent.* | *Per cent.* 95.9 | *Per cent.* 97.2 | *Per cent.* 98.2 | *Per cent.* 75.6 | *Per cent.* 96.9 |
| | Estimated coefficients of digestibility of bread | | 94.4 | | 98.3 | | a 98.5 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | | | | | | 92.7 |
| | In bread alone | | | | | | a 95.1 |

a Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 6,556.6 grams urine, containing 92.45 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 26.81 grams; outgo in urine, 23.11 grams, and in feces, 1.05 grams, implying a gain of 2.65 grams, nitrogen, corresponding to 16.6 grams protein.

## DIGESTION EXPERIMENT NO. 317.

*Kind of food.*—Milk, and bread made from straight flour.

*Subject.*—Man No. 3, as in experiment No. 311.

*Weight.*—At the beginning of the experiment, 151 pounds; at the close, 150.25 pounds.

*Duration.*—Four days, with twelve meals, beginning with breakfast April 28, 1902.

TABLE 26.—*Results of digestion experiment No. 317.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 241 | Bread | 3,330.0 | 252.7 | 12.6 | 1,820.3 | 16.3 | 8,691 |
| 243 | Milk | 10,150.0 | 303.5 | 415.1 | 488.2 | 78.2 | 7,531 |
| | Total | | 556.2 | 427.7 | 2,308.5 | 94.5 | 16,222 |
| 247 | Feces (water free) | 127.0 | 32.2 | 19.4 | 41.4 | 34.1 | 681 |
| | Estimated feces from food other than bread | | 9.1 | | 9.8 | | |
| | Estimated feces from bread | | 23.1 | | 31.6 | | |
| | Total amount digested | | 524.0 | 408.3 | 2,267.1 | 60.4 | 15,541 |
| | Estimated digestible nutrients in bread | | 229.6 | | 1,788.7 | | |
| | Coefficients of digestibility of total food | *Per cent.* | *Per cent.* 94.2 | *Per cent.* 95.5 | *Per cent.* 98.2 | *Per cent.* 63.9 | *Per cent.* 95.8 |
| | Estimated coefficients of digestibility of bread | | 90.9 | | 98.2 | | *a* 97.4 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | | | | | | 91.8 |
| | In bread alone | | | | | | *a* 94.1 |

*a* Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 4,747.6 grams urine, containing 65.99 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 23.22 grams; outgo in urine, 16.50 grams, and in feces, 1.29 grams, implying a gain of 5.43 grams nitrogen, corresponding to 33.9 grams protein.

## DIGESTION EXPERIMENT NO. 318.

*Kind of food.*—Milk, and bread made from entire-wheat flour.

*Subject.*—Man No. 1, as in experiment No. 309.

*Weight.*—At the beginning of the experiment, 167.25 pounds; at the close, 168 pounds.

*Duration.*—Four days, with twelve meals, beginning with breakfast May 5, 1902.

TABLE 27.—*Results of digestion experiment No. 318.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 251 | Bread | 3,700.0 | 308.2 | 40.0 | 1,913.0 | 47.0 | 9,952 |
| 258 | Milk | 12,000.0 | 360.0 | 462.0 | 570.0 | 87.6 | 8,820 |
| | Total | | 668.2 | 502.0 | 2,483.0 | 134.6 | 18,772 |
| 252 | Feces (water free) | 287.0 | 51.5 | 15.2 | 161.5 | 58.8 | 1,231 |
| | Estimated feces from food other than bread | | 10.8 | | 11.4 | | |
| | Estimated feces from bread | | 40.7 | | 150.1 | | |
| | Total amount digested | | 616.7 | 486.8 | 2,321.5 | 75.8 | 17,541 |
| | Estimated digestible nutrients in bread | | 267.5 | | 1,762.9 | | |

TABLE 27.—*Results of digestion experiment No. 318*—Continued.

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Coefficients of digestibility of total food | *Per cent.* | *Per cent.* 92.3 | *Per cent.* 97.0 | *Per cent.* 98.5 | *Per cent.* 56.3 | *Per cent.* 93.4 |
| | Estimated coefficients of digestibility of bread | | 86.8 | | 92.2 | | [a] 91.3 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | | | | | | 89.3 |
| | In bread alone | | | | | | [a] 87.9 |

[a] Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 7,889.1 grams urine, containing 84.41 grams nitrogen. The total nitrogen balance for four days was therefore as follows: Income in food, 27.92 grams; outgo in urine, 21.10 grams, and in feces, 2.06 grams, implying a gain of 4.76 grams nitrogen, corresponding to 29.8 grams protein.

## DIGESTION EXPERIMENT NO. 319.

*Kind of food.*—Milk, and bread made from entire-wheat flour.

*Subject.*—Man No. 2, as in experiment No. 310.

*Weight.*—At the beginning and close of the experiment, 167.5 pounds.

*Duration.*—Four days, with twelve meals, beginning with breakfast May 5, 1902.

TABLE 28.—*Results of digestion experiment No. 319.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 251 | Bread | 3,655.0 | 304.5 | 39.5 | 1,889.5 | 46.4 | 9,831 |
| 258 | Milk | 12,380.0 | 371.4 | 476.6 | 588.0 | 90.4 | 9,100 |
| | Total | | 675.9 | 516.1 | 2,477.5 | 136.8 | 18,931 |
| 253 | Feces (water free) | 302.0 | 63.4 | 35.2 | 140.1 | 63.3 | 1,332 |
| | Estimated feces from food other than bread | | 11.1 | 23.8 | 11.8 | | 351 |
| | Estimated feces from bread | | 52.3 | 11.4 | 128.3 | | 981 |
| | Total amount digested | | 612.5 | 480.9 | 2,337.4 | 73.5 | 17,599 |
| | Estimated digestible nutrients in bread | | 252.2 | 28.1 | 1,761.2 | | 8,850 |
| | Coefficients of digestibility of total food | *Per cent.* | *Per cent.* 90.6 | *Per cent.* 93.2 | *Per cent.* 94.3 | *Per cent.* 53.7 | *Per cent.* 92.9 |
| | Estimated coefficients of digestibility of bread | | 82.8 | 71.1 | 93.2 | | 90.0 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | | | | | | 88.9 |
| | In bread alone | | | | | | 86.8 |

During this experiment the subject eliminated 6,910.1 grams urine, containing 101.58 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 28.21 grams; outgo in urine,

25.39 grams, and in feces, 2.57 grams, implying a gain of 0.25 gram nitrogen, corresponding to 1.6 grams protein.

### DIGESTION EXPERIMENT NO. 320.

*Kind of food.*—Milk, and bread made from entire-wheat flour.

*Subject.*—Man No. 3, as in experiment No. 311.

*Weight.*—At the beginning of the experiment, 150 pounds; at the close, 151.5 pounds.

*Duration.*—Four days, with twelve meals, beginning with breakfast May 5, 1902.

TABLE 29.—*Results of digestion experiment No. 320.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 251 | Bread | 3,650.0 | 304.0 | 39.4 | 1,887.1 | 46.3 | 9,818 |
| 258 | Milk | 11,750.0 | 352.5 | 452.4 | 558.1 | 85.8 | 8,636 |
| | Total | | 656.5 | 491.8 | 2,445.2 | 132.1 | 18,454 |
| 254 | Feces (water free) | 262.0 | 48.9 | 15.7 | 135.6 | 61.7 | 1,045 |
| | Estimated feces from food other than bread | | 10.6 | | 11.2 | | |
| | Estimated feces from bread | | 38.3 | | 124.4 | | |
| | Total amount digested | | 607.6 | 476.1 | 2,309.6 | 70.4 | 17,409 |
| | Estimated digestible nutrients in bread | | 265.7 | | 1,762.7 | | |
| | Coefficients of digestibility of total food | *Per cent.* | *Per cent.* 92.5 | *Per cent.* 96.8 | *Per cent.* 94.4 | *Per cent.* 53.3 | *Per cent.* 94.3 |
| | Estimated coefficients of digestibility of bread | | 87.4 | | 93.4 | | [a] 92.7 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | | | | | | 90.2 |
| | In bread alone | | | | | | [a] 89.4 |

[a] Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 5,476.6 grams urine, containing 88.17 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 27.44 grams; outgo in urine, 22.04 grams, and in feces 1.96 grams, implying a gain of 3.44 grams nitrogen, corresponding to 21.5 grams protein.

### DIGESTION EXPERIMENT NO. 321.

*Kind of food.*—Milk, and bread made from graham flour.

*Subject.*—Man No. 1, as in experiment No. 309.

*Weight.*—At the beginning of the experiment, 169.75 pounds; at the close, 170 pounds.

*Duration.*—Four days, with twelve meals, beginning with breakfast May 16, 1902.

TABLE 30.—*Results of digestion experiment No. 321.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 260 | Bread | 3,695.0 | 308.9 | 32.2 | 1,891.8 | 53.6 | 9,681 |
| 259 | Milk | 11,850.0 | 385.1 | 527.3 | 596.1 | 91.2 | 9,207 |
| | Total | | 694.0 | 559.5 | 2,487.9 | 144.8 | 18,888 |
| 261 | Feces (water free) | 389.0 | 75.9 | 25.1 | 222.0 | 66.1 | 1,641 |
| | Estimated feces from food other than bread | | 11.6 | | 11.9 | | |
| | Estimated feces from bread | | 64.3 | | 210.1 | | |
| | Total amount digested | | 618.1 | 534.4 | 2,265.9 | 78.7 | 17,247 |
| | Estimated digestible nutrients in bread | | 244.6 | | 1,681.7 | | |
| | Coefficients of digestibility of total food | *Per cent.* | *Per cent.* 89.1 | *Per cent.* 95.5 | *Per cent.* 91.1 | *Per cent.* 54.4 | *Per cent.* 91.3 |
| | Estimated coefficients of digestibility of bread | | 79.2 | | 88.9 | | *a* 85.8 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | | | | | | 87.2 |
| | In bread alone | | | | | | *a* 82.7 |

*a* Calculated according to the assumption that 90 per cent of the fat in the bread is digestible.

During this experiment the subject eliminated 5,211 grams urine, containing 73.48 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 28.95 grams; outgo in urine, 18.37 grams, and in feces, 3.04 grams, implying a gain of 7.54 grams nitrogen, corresponding to 47.1 grams protein.

## DIGESTION EXPERIMENT NO. 322.

*Kind of food.*—Milk, and bread made from graham flour.

*Subject.*—Man No. 2, as in experiment No. 310.

*Weight.*—At the beginning and close of the experiment, 166.5 pounds.

*Duration.*—Four days, with twelve meals, beginning with breakfast May 16, 1902.

TABLE 31.—*Results of digestion experiment No. 322.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 260 | Bread | 3,455.0 | 288.8 | 30.1 | 1,768.9 | 50.1 | 9,052 |
| 259 | Milk | 11,750.0 | 381.9 | 522.9 | 591.0 | 90.5 | 9,130 |
| | Total | | 670.7 | 553.0 | 2,359.9 | 140.6 | 18,182 |
| 262 | Feces (water free) | 387.0 | 69.1 | 54.1 | 197.9 | 65.9 | 1,730 |
| | Estimated feces from food other than bread | | 11.5 | 26.1 | 11.8 | | 361 |
| | Estimated feces from bread | | 57.6 | 28.0 | 186.1 | | 1,369 |
| | Total amount digested | | 601.6 | 498.9 | 2,162.0 | 74.7 | 16,452 |
| | Estimated digestible nutrients in bread | | 231.2 | 2.1 | 1,582.8 | | 7,683 |

TABLE 31.—*Results of digestion experiment No. 322*—Continued.

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Coefficients of digestibility of total food | *Per cent.* | *Per cent.* 89.7 | *Per cent.* 90.2 | *Per cent.* 91.6 | *Per cent.* 53.1 | *Per cent.* 90.5 |
| | Estimated coefficients of digestibility of bread | | 80.1 | 7.0 | 89.5 | | 84.9 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | | | | | | 86.3 |
| | In bread alone | | | | | | 81.7 |

During this experiment the subject eliminated 4,532 grams urine, containing 52.57 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 27.94 grams; outgo in urine, 13.14 grams, and in feces, 2.76 grams, implying a gain of 12.04 grams nitrogen, corresponding to 75.2 grams protein.

## DIGESTION EXPERIMENT NO. 323.

*Kind of food.*—Milk, and bread made from graham flour.

*Subject.*—Man No. 3, as in experiment No. 311.

*Weight.*—At the beginning of the experiment, 151.25 pounds; at the close, 150.5 pounds.

*Duration.*—Four days, with twelve meals, beginning with breakfast May 16, 1902.

TABLE 32.—*Results of digestion experiment No. 323.*

| Sample No. | | Weight of material. | Protein. | Fat. | Carbohydrates. | Ash. | Heat of combustion. |
|---|---|---|---|---|---|---|---|
| | Food consumed: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 260 | Bread | 3,580.0 | 299.3 | 31.1 | 1,832.9 | 51.9 | 9,379 |
| 259 | Milk | 11,000.0 | 357.5 | 489.5 | 553.3 | 84.7 | 8,546 |
| | Total | | 656.8 | 520.6 | 2,386.2 | 136.6 | 17,925 |
| 263 | Feces (water free) | 384.0 | 73.4 | 31.7 | 202.3 | 76.6 | 1,601 |
| | Estimated feces from food other than bread | | 10.7 | 24.5 | 11.1 | | 348 |
| | Estimated feces from bread | | 62.7 | 7.2 | 191.2 | | 1,253 |
| | Total amount digested | | 583.4 | 488.9 | 2,183.9 | 60.0 | 16,324 |
| | Estimated digestible nutrients in bread | | 236.6 | 23.9 | 1,641.7 | | 8,126 |
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| | Coefficients of digestibility of total food | | 88.8 | 93.9 | 91.5 | 43.9 | 91.1 |
| | Estimated coefficients of digestibility of bread | | 79.0 | 76.8 | 89.6 | | 86.6 |
| | Proportion of energy actually available to body: | | | | | | |
| | In total food | | | | | | 87.0 |
| | In bread alone | | | | | | 83.5 |

During this experiment the subject eliminated 4,509 grams urine, containing 85.16 grams nitrogen. The total nitrogen balance per day was therefore as follows: Income in food, 27.42 grams; outgo in

urine, 21.29 grams, and in feces, 2.94 grams, implying a gain of 3.19 grams nitrogen, corresponding to 19.9 grams protein.

## SUMMARY OF RESULTS OBTAINED WITH SOFT WINTER WHEAT PRODUCTS.

In Table 33 a summary is given of the digestibility of the nutrients and availablity of the energy of the entire food of the various digestion experiments with milk and white bread from mixed-grade flour, white bread from straight-grade flour, entire-wheat bread, and graham, all ground from soft winter wheat.

TABLE 33.—*Summary of digestion experiments with soft winter wheat; digestibility of nutrients and availability of energy of total food.*

| Experiment No. | Subject No. | Kind of food. | Protein. | Fat. | Carbohydrates. | Energy. |
|---|---|---|---|---|---|---|
| | | Experiments with Indiana wheat: | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 309 | 1 | Milk and white bread (mixed grade) | 95.8 | 93.7 | 96.2 | 90.4 |
| 310 | 2 | ....do | 93.4 | 93.5 | 96.9 | 90.3 |
| 311 | 3 | ....do | 90.3 | 95.5 | 96.2 | 90.4 |
| | | Average of 3 | 93.2 | 94.2 | 96.4 | 90.4 |
| 312 | 1 | Milk and entire-wheat bread | 93.6 | 97.1 | 92.1 | 88.6 |
| 313 | 2 | ....do | 91.6 | 93.8 | 91.7 | 87.7 |
| 314 | 3 | ....do | 88.8 | 97.0 | 90.8 | 87.5 |
| | | Average of 3 | 91.3 | 96.0 | 91.5 | 87.9 |
| | | Experiments with Michigan wheat: | | | | |
| 315 | 1 | Milk and white bread (standard patent) | 95.2 | 97.7 | 97.7 | 92.2 |
| 316 | 2 | ....do | 95.9 | 97.2 | 98.2 | 92.7 |
| 317 | 3 | ....do | 94.2 | 95.5 | 98.2 | 91.8 |
| | | Average of 3 | 95.1 | 96.8 | 98.0 | 92.2 |
| 318 | 1 | Milk and entire-wheat bread | 92.3 | 97.0 | 93.5 | 89.3 |
| 319 | 2 | ....do | 90.6 | 93.2 | 94.3 | 88.9 |
| 320 | 3 | ....do | 92.5 | 96.8 | 94.4 | 90.2 |
| | | Average of 3 | 91.8 | 95.7 | 94.1 | 89.5 |
| 321 | 1 | Milk and graham bread | 89.1 | 95.5 | 91.1 | 87.2 |
| 322 | 2 | ....do | 89.7 | 90.2 | 91.6 | 86.2 |
| 323 | 3 | ....do | 88.8 | 93.9 | 91.5 | 87.0 |
| | | Average of 3 | 89.2 | 93.2 | 91.4 | 86.8 |

The results summarized in the table show that, in general, the ration consisting of milk and white bread made from the patent grade flour was more digestible than the rations of milk and bread made from either of the other kinds of flour, also that a larger percentage of energy was available to the body in the case of white bread and milk than from the entire-wheat or graham bread and milk.

In the experiments with Indiana soft wheat individual differences as regards the ability to digest the bread and milk rations were quite pronounced with the various subjects; in the case of the white bread, a difference of about 5.5 per cent in the digestibility of the protein being observed. Subject No. 1 digested the wheat bread and also the entire-wheat bread more completely than did subject No. 2 or No. 3. With

each subject, however, the digestibility of the ration with white bread was greater than that with entire wheat. In the experiments with Michigan soft wheat individual differences are noticeable, but they are less pronounced, and, as was the case with the other wheats, each subject digested the ration of white bread and milk more completely than bread made from either of the other flours.

In Table 34 the calculated digestibility of the nutrients and availability of the energy of the bread alone are given:

TABLE 34.—*Summary of digestion experiments with soft winter wheat; digestibility of nutrients and availability of energy of bread alone.*

| Experiment No. | Subject No. | Kind of food. | Protein. | Carbohydrates. | Energy. |
|---|---|---|---|---|---|
| | | Experiments with Indiana wheat: | *Per cent.* | *Per cent.* | *Per cent.* |
| 309 | 1 | White bread (mixed grade flour) | 94.2 | 95.6 | 90.4 |
| 310 | 2 | ....do | 89.4 | 96.6 | 90.4 |
| 311 | 3 | ....do | 83.0 | 95.8 | 90.4 |
| | | Average of 3 | 88.9 | 96.0 | 90.4 |
| 312 | 1 | Entire-wheat bread | 89.5 | 90.3 | 85.2 |
| 313 | 2 | ....do | 84.9 | 89.8 | 84.5 |
| 314 | 3 | ....do | 79.3 | 88.8 | 82.9 |
| | | Average of 3 | 84.6 | 89.6 | 84.2 |
| | | Experiments with Michigan wheat: | | | |
| 315 | 1 | White bread (standard patent) | 93.0 | 97.6 | 93.4 |
| 316 | 2 | ....do | 94.4 | 98.3 | 95.1 |
| 317 | 3 | ....do | 90.9 | 98.2 | 94.1 |
| | | Average of 3 | 92.8 | 98.0 | 94.2 |
| 318 | 1 | Entire-wheat bread | 86.8 | 92.2 | 87.9 |
| 319 | 2 | ....do | 82.8 | 93.2 | 86.8 |
| 320 | 3 | ....do | 87.4 | 93.4 | 89.4 |
| | | Average of 3 | 85.7 | 92.9 | 88.0 |
| 321 | 1 | Graham bread | 79.2 | 88.9 | 82.7 |
| 322 | 2 | ....do | 80.1 | 89.5 | 81.7 |
| 323 | 3 | ....do | 79.0 | 89.6 | 83.5 |
| | | Average of 3 | 79.4 | 89.3 | 82.6 |

These results are calculated, as explained on page 19, by assuming that 97 per cent of the protein and 98 per cent of the carbohydrates of the milk were digested.[a]

The average result of the experiments with flour milled from Indiana soft winter wheat shows that 88.9 per cent of the protein and 96 per cent of the carbohydrates of the white bread from mixed-grade flour were digested, and that 90.4 per cent of the energy was available. As regards the bread from entire-wheat flour, ground from the same lot of wheat, 84.6 per cent of the protein and 89.6 per cent of the car-

[a] It was also assumed that 95 per cent of the fat of the milk would be digested, but with this factor the digestibility of the fat of bread could be computed satisfactorily in only a few cases; therefore figures for this constituent are left out of Table 34. In all cases where the digestibility of bread fat could not be computed it was assumed, in order to estimate the available energy of the bread, that 90 per cent would be digested.

bohydrates were found to be digestible, and 84.2 per cent of the energy to be available. It will be observed, further, that with each of the subjects the nutrients of the white bread were more digestible and the energy more available than was the case with the entire-wheat bread.

The white bread made from straight-grade flour milled from Michigan soft winter wheat had the highest digestibility of any of the samples ground from this variety, namely, 92.8 per cent of the protein and 98 per cent of the carbohydrates, while 94.2 per cent of the energy was available to the body. Of the protein of bread from the entire-wheat flour milled from the same lot of wheat, 85.7 per cent, and of the carbohydrates 92.9 per cent were digestible, 88 per cent of the energy being available to the body. The lowest coefficients of digestibility were found in the graham bread, the values being 79.4 per cent for the protein, 89.3 per cent for the carbohydrates, and 82.6 per cent for the energy available to the body. As will be seen, there was a difference of 13.4 per cent in the average digestibility of the protein of the graham bread and white bread made of flour from the same lot of wheat, while 8.7 per cent less of the carbohydrates of the graham bread was digestible, and 11.6 per cent less of the energy was available. As in the case of the entire ration, differences attributable to individuality are noticeable, which are, however, not great enough to invalidate the general deduction that white bread is the most digestible, graham bread the least, and entire-wheat bread intermediate between them.

Table 35 gives a summary of the experiments on the basis of the proportion of total and digestible nutrients and available energy in the different grades of flour as milled from soft winter wheat:

TABLE 35.—*Proportion of total and digestible nutrients and available energy in different grades of soft winter-wheat flour as milled.*

| Number of sample. | Grade of flour. | Protein. | | Carbohydrates. | | Heat of combustion per gram. | |
|---|---|---|---|---|---|---|---|
| | | Total. | Digestible. | Total. | Digestible. | Total. | Available. |
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Calories.* | *Calories.* |
| 221 | Mixed-grade flour | 12.30 | 10.93 | 75.94 | 72.90 | 4.010 | 3.645 |
| 219 | Entire-wheat flour | 12.80 | 10.82 | 74.40 | 66.66 | 4.020 | 3.384 |
| 240 | Straight white flour | 10.92 | 10.13 | 77.15 | 75.61 | 3.799 | 3.579 |
| 241 | Entire-wheat flour | 12.01 | 10.29 | 74.17 | 68.80 | 3.860 | 3.399 |
| 242 | Graham flour | 12.24 | 9.72 | 73.27 | 65.43 | 3.906 | 3.226 |

The digestible nutrients were obtained by multiplying the percentage of the total nutrients by the average digestion coefficients given in Table 34. The mixed-grade flour, for example, contained 12.3 per cent total protein, which was found to be 88.9 per cent digestible, being therefore equivalent to 10.93 per cent of digestible protein. The mixed-grade flour prepared from the Indiana wheat contained 10.93 per cent digestible protein, 72.90 per cent digestible carbo-

hydrates, and 1 gram of the flour yielded 3.645 calories of available energy. The entire-wheat flour prepared from the same wheat yielded 10.82 per cent digestible protein, 66.87 per cent digestible carbohydrates, and 3.375 available calories per gram. The difference in digestible protein is small, being 0.11 per cent in favor of the mixed-grade flour. The difference in the digestible carbohydrates is quite large, being 6.24 per cent in favor of the mixed-grade flour. The difference in the available energy is also large, amounting to 0.261 calorie per gram in favor of the white flour.

While there is no material difference as to the amount of digestible protein in the two kinds of flour, the differences in digestible carbohydrates and available energy are decidedly in favor of the mixed-grade flour. The entire-wheat flour contained a larger amount of protein, but, as shown in Table 34, this protein is less digestible than that of the mixed-grade flour, which was more finely granulated.

The straight-grade flour prepared from the Michigan wheat contained 10.13 per cent digestible protein, 75.61 per cent digestible carbohydrates, and 3.574 calories of available energy per gram. Compared with graham flour, this shows 0.4 per cent of digestible protein, 10.18 per cent of digestible carbohydrates, and 0.353 calorie of available energy per gram in favor of the white flour. Compared with the entire-wheat flour, the results show a difference of 6.81 per cent digestible carbohydrates and 0.180 available energy per gram in favor of the straight-grade flour; the difference in digestible protein, though too small to be of significance, is 0.16 per cent in favor of the entire-wheat flour. In the description of the samples it was stated that the straight-grade flour did not contain all of the granular middlings which are usually included in the preparation of ordinary straight flours. Had the flour contained the granular middlings, the percentage of protein, it seems fair to conclude, would have been higher than 10.92. While the difference in total protein is 1.1 per cent in favor of the entire-wheat flour, the higher degree of digestibility of this constituent in the straight-grade flour makes the figures for the total digestible protein in the two kinds of flour practically the same. Hence, what is gained from the somewhat larger amount of protein in the entire-wheat and graham flours is lost in digestibility. While the difference between the digestible protein in the straight-grade and entire-wheat flours prepared from the same lot of soft wheat is small, the difference in digestible carbohydrates is large, being 6.8 per cent in favor of the white flour. Since a larger amount of digestible carbohydrates and available energy is secured from the mixed and straight-grade flours than from the entire-wheat flour and no appreciable differences were observed as to digestible protein, it would appear that a larger total amount of nutrients and energy is available to the

body from the straight than from the entire-wheat or graham flours, a conclusion in accord with the results of all our former work.

That the lower degree of digestibility of the entire-wheat and graham flours was probably due at least in part to a coarser granulation of the particles, which consequently exposed a relatively smaller amount of surface to the action of the digestive fluids, was shown by a microscopical examination of the feces. The feces from both the entire-wheat and the graham flours under the microscope showed a larger proportion of starch particles that had not been acted upon in the digestive tract than the feces from standard patent flour. The micro-photographs reproduced (Pls. I–III) show the fineness of division of the three sorts of flour and the starch granules in the feces obtained from the standard patent, the entire-wheat, and the graham flours, prepared by grinding in a mortar.

These deductions are in accord with the results of numerous microscopical studies of the feces from different sorts of wheat products, and in this connection it is interesting to refer to some of these and closely related investigations. Among others may be mentioned the work of Rubner,[a] Pappenheim,[b] Constantinidi,[c] and Raudnitz.[d]

In general it may be said that these investigators found that starch was very thoroughly digested, but that the cells making up the outer portion of the wheat berry were little attacked by the digestive juices, and hence the contents of such cells were not assimilated. Rubner pointed out that the amount of undigested nitrogen increased with an increase in the amount of the outer portion of the grain retained in flour in milling. Rathay[e] reports experimental studies, of which he himself was the subject, in which the diet for a week consisted of graham bread and tea. The bread was made without leaven or yeast. The feces from the fifth and seventh day were examined microscopically. He found that the grain portions which had been little masticated were softened, but almost entirely undigested. From only a few of the outer cells of the endosperm had the starch grains and the proteid materials disappeared, while the greater part of these nutrients was excreted unchanged. The general conclusion from his investigations was that the greater portion of the feces consisted of undigested residues of wheat bran in the form of large flakes composed of the seed coats and aleurone layer. The latter leaves the intestines unchanged, probably because the thick walls of the aleurone cells prevent the action of digestive juices upon the cell contents. So far as can be learned, this investigation was the first which at all satisfac-

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[a] Ztschr. Biol., 15 (1879), p. 115.

[b] Lehrbuch der Müllerei (1890), 3d ed., cited by Moeller.

[c] Ztschr. Biol., 23 (1887), p. 447.

[d] Prag. med. Wchnschr., 7 (1892), pp. 1, 13.

[e] Jahresber. K. K. Realschule Sechshaus, Wien, 1874, cited by Moeller.

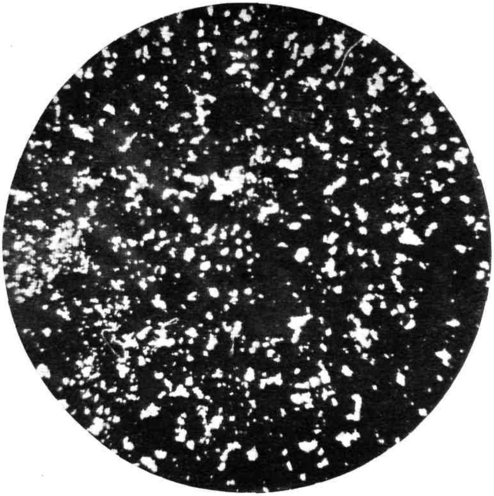

FIG. 1.—FLOUR PARTICLES FROM STRAIGHT PATENT FLOUR NO. 240 (MAGNIFIED 15 DIAMETERS).

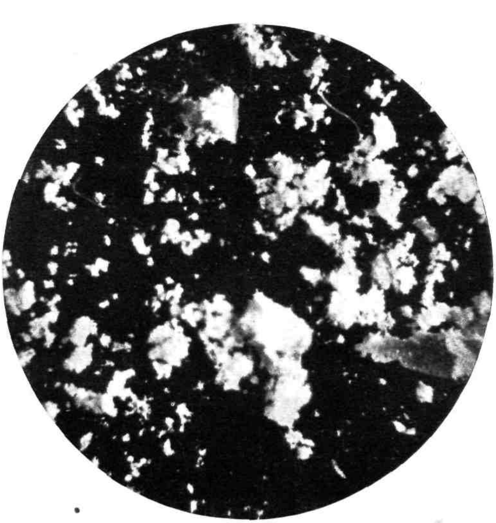

FIG. 2.—FLOUR PARTICLES FROM ENTIRE-WHEAT FLOUR NO. 241 (MAGNIFIED 15 DIAMETERS).

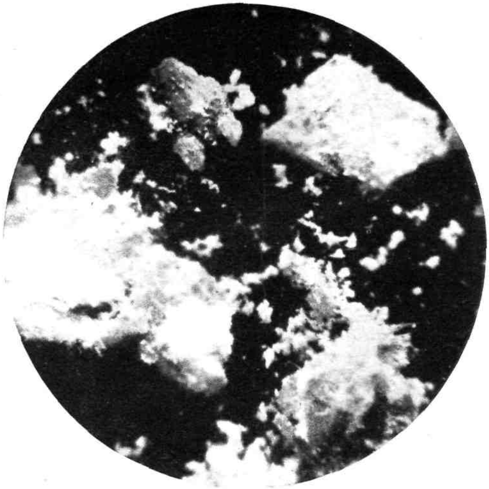

FIG. 1.—FLOUR PARTICLES FROM GRAHAM FLOUR NO. 243 (MAGNIFIED 15 DIAMETERS).

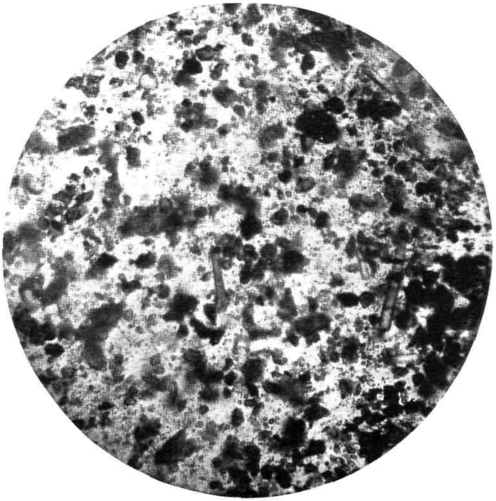

FIG. 2.—FECES FROM BREAD MADE FROM STRAIGHT PATENT FLOUR (MAGNIFIED 15 DIAMETERS).

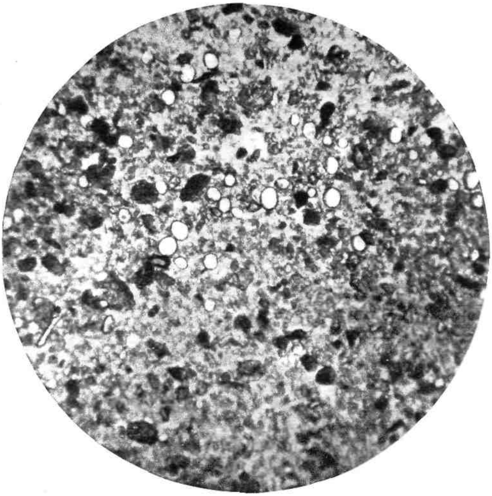

FIG. 1.—FECES FROM BREAD MADE FROM GRAHAM FLOUR (MAGNIFIED 15 DIAMETERS).

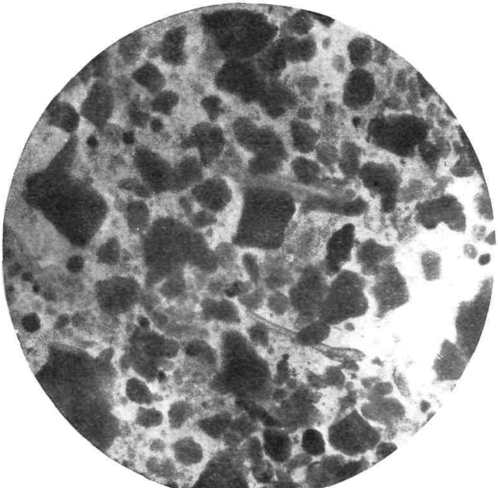

FIG. 2.—FECES FROM BREAD MADE FROM ENTIRE-WHEAT FLOUR (MAGNIFIED 15 DIAMETERS).

torily opposed Liebig's idea of the high value of the gluten layer of wheat.

Perhaps the most extended study of vegetable residues occurring in feces was made by Moeller[a]. In some of the experiments the diet consisted of coarse bread with butter and cheese; white bread, rice, and butter; bread, and porridge made of wheat grits and milk; bread, and porridge made from milk and flour; oat preparations, namely, oat grits, oat flake, soup, and oat cocoa; rye bread and various mixed diets, or diets in which potatoes or legumes predominated. Portions of feces were repeatedly washed with water and then examined under the microscope. The conclusion was reached that healthy individuals digested the starch of cereals and potatoes almost completely, even when the starchy foods were not in favorable mechanical condition, as is the case in bran from cereals, in rice, or in sliced potatoes; and further, that the soft cell walls of the starch cells are also digested. The aleurone layer of cereals in which the cell membranes consist of pure cellulose was not digested, nor were the protein and fat which form the contents of the cells digested unless the cell walls had been mechanically ruptured. The cells making up the germ were not digested or ruptured by the action of the digestive juices. The author believes that these experiments warrant the conclusion that fine flour is preferable to coarse flour. Comparative experiments with coarse flour and the same flour after passing through the intestinal tract, lead the author to the conclusion that the cell walls almost absolutely shield the cell contents of the aleurone layer from the action of the digestive juices, and he concludes that cereal brans should be regarded as indigestible. The outer layer of the cereal grains, including endosperm cells with their starch content, was also found to be undigested.

Laboratory experiments indicated that cellulose which had not lignified was little attacked by digestive juices, the amount being inversely proportional to the thickness of the cell membrane. On the other hand, the middle lamellæ were readily disintegrated by digestive juices. Tests with laboratory reagents also showed that the inner side of the gluten cells was most resistant but after a time softened, and this indicates that possibly gluten cells may become softened in the intestine and then digested. That this occurs very seldom is indicated by the large number of unchanged cells found in the feces.

As noted above, in connection with the experiments reported in this bulletin, a microscopical examination of the feces showed that in those from the graham and entire-wheat breads made from flour ground from the same lot of soft wheat, a much larger number of unaltered starch granules were present, and the particles had not been as completely acted upon by the digestive fluids as in the case of the straight-grade-flour bread.

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[a] Ztschr. Biol., 35 (1897), p. 291.

Summarizing briefly the results of the fifteen experiments with soft-wheat flours, it appears that while the graham and entire-wheat flours contain a larger amount of protein and energy, the lower degree of digestibility of these flours, due to the coarser granulation, renders available to the body a smaller proportion of total nutrients as well as energy than in the case of straight-grade flours, ground from the same wheat, which are more finely granulated and more completely digested. This is entirely in accord with the results obtained in the investigations with hard-wheat flours more exhaustively milled.

As was the case in the tests with bread from different grades of hard-wheat flour, no variations were observed in the metabolism of nitrogen which could be attributed to the use of the different sorts of flour constituting the principal part of the diet.

## GENERAL SUMMARY OF RESULTS AND CONCLUSIONS.

The experiments with hard wheat milling products reported in the present bulletin are the latest of a fairly extended series which has given uniform results. The experiments with soft wheat are the first of a proposed series and are less numerous than those made with hard wheat. The results already obtained, however, are in accord with what has been learned regarding the milling products of hard wheat. Some general deductions from the experiments as a whole seem warranted.

As shown by analysis the patent flour, ground from the hard and soft wheats studied, had a somewhat lower protein content than the graham flour and entire-wheat flour ground from the same wheats, but according to the results of digestion experiments with the different grades of flour from these wheats, the proportion of digestible protein and the available energy in the patent flour was larger than in the coarser grades. The lower digestibility of the protein in the latter is, it appears, due to the fact that in these grades a considerable portion of this constituent is contained in the coarser particles (bran) and thus escapes digestion as it is not acted upon by the digestive juices. Thus, while there may be actually more protein in a given amount of graham or entire-wheat flour than in an equal amount of patent flour ground from the same wheat, the body secures less of the protein and energy from the coarse flour than it does from the fine, since although the retention of the bran and germ increases the percentage of protein it decreases the digestibility. By digestibility is meant the difference between the amounts of the several nutrients consumed and the amounts excreted in the feces. No attempt was made to study the ease or rapidity of digestion of the different sorts of flour. When the digestibility of different grades of patent flour was studied it was found that there was no marked difference between standard patent

flour and the other grades in this respect. The digestibility of all these flours was found to be high, apparently owing largely to their mechanical condition, that is, owing to the fact that they were finely ground.

Microscopical studies of the feces from bread made from the different grades of flour indicate that the superior digestibility of patent-flour bread is due to the fineness of division of the flour particles and also to the fact that the cell walls of the material making up the interior of the wheat berry are less resistant to digestive juices than the walls of the cells making up the outer layers of the grain. In other words, the patent flour is superior as regards digestibility, on account of both its mechanical condition and its physical properties.

In discussions of the comparative value of fine wheat flour and the coarser grades, it is often claimed that the larger proportion of mineral matter, and especially phosphorous compounds, in whole-wheat and graham flours is a reason for preferring them to patent flour. In this case also it is undoubtedly true that the proportion of mineral constituents which is digestible, or, in other words, which the body can retain, from the different sorts of flour, must be considered, as well as the amounts which chemical analysis shows to be present in the food. In view of the fact that there is apparently no satisfactory method for determining the proportion of ash in the feces, derived from metabolic products, and that it is, therefore, impossible by present methods to determine the true digestibility of the mineral constituents, no values for the digestibility of ash have been included in the present bulletin. It may be noted in this connection that it is a well-recognized fact that when the coarser milling products are fed to cattle no great amount of phosphorus (one of the most important manurial elements) is retained in the animal body. This may possibly be an indication that the phosphorus, even if present in considerable amounts in the feed, is not in a form which can be assimilated by animals. This is, however, little more than conjecture, and more experiments with man and the lower animals are needed before satisfactory conclusions can be drawn.

Briefly stated, the most important deductions from the results of these investigations with hard and soft wheat are in accord with the conclusions drawn from the earlier investigations of this series. The nutritive value of flour, in so far as the quantities of digestible protein, fats, and carbohydrates, and available energy are concerned, is not increased by milling the wheat in such a way as to retain a large proportion of bran and germ. The differences in the amounts of total nutrients furnished the body by the various grades of flour are, however, relatively small, all grades being quite thoroughly digested. The coarser flours have a tendency to increase peristaltic action, and are on this account especially valuable for some persons. Judged by

composition and digestibility, all the flours are very nutritious foods, which experience has shown are wholesome as well. When also the fact is taken into account that they furnish nutritive material in an economical form, their importance is evident. The fact must not be lost sight of that using different grades of flour for bread making and other household purposes offers a convenient method of adding to the variety of the daily diet, a matter which is of undoubted importance.

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